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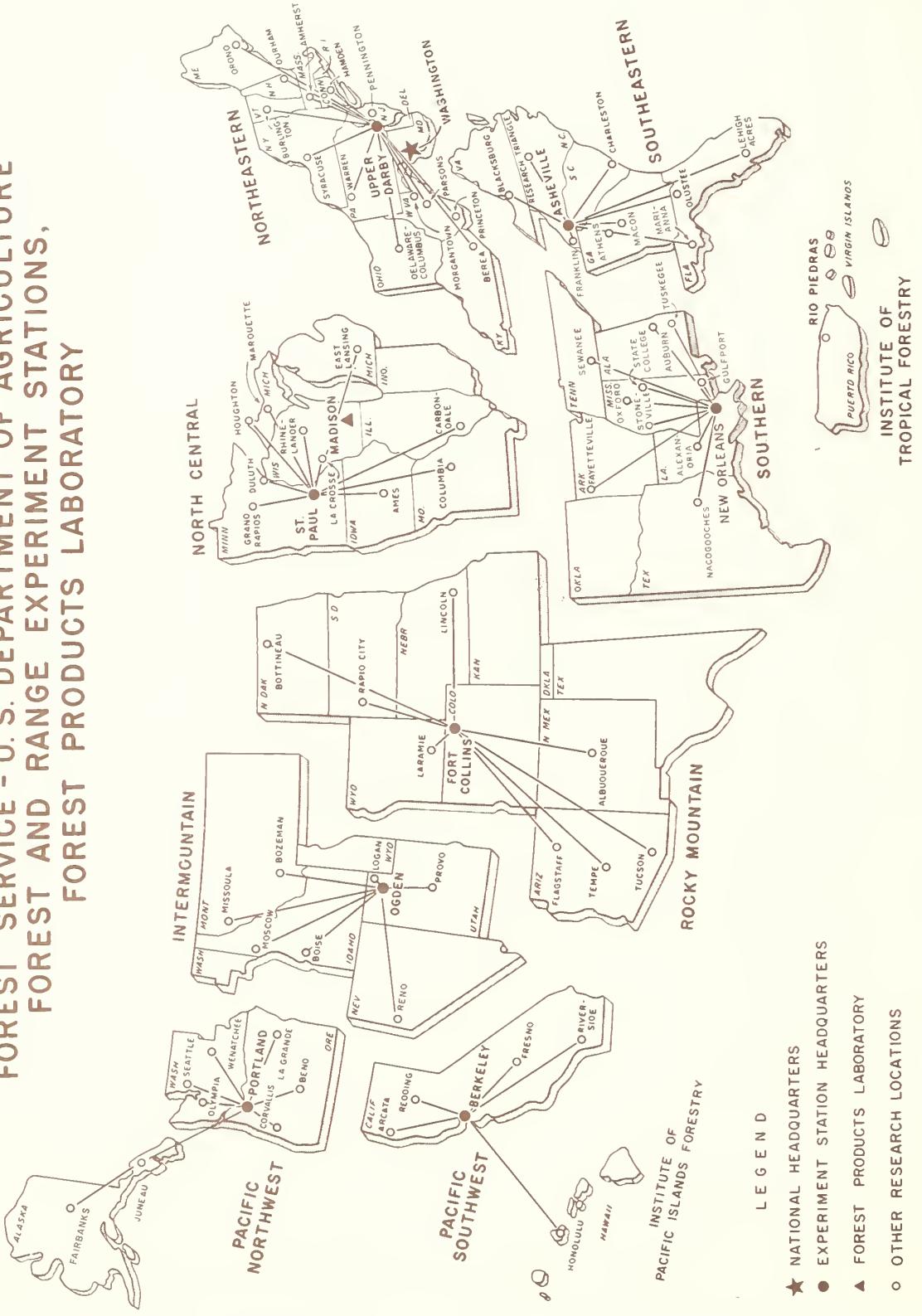
A close-up photograph of a tree trunk, likely a conifer, showing detailed, textured bark with many fissures and lichen. The lighting highlights the depth of the bark's surface.

forest
Service
research
accomplishments / 1972

UNITED STATES DEPARTMENT OF AGRICULTURE • FOREST SERVICE

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE
FOREST AND RANGE EXPERIMENT STATIONS,
FOREST PRODUCTS LABORATORY

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
Washington, D. C. 20250

1380 (4000)

Dr. T. K. Cowden
Assistant Secretary
U.S. Department of Agriculture
Washington, D. C. 20250



Dear Dr. Cowden:

As a former researcher, I take particular pleasure in sending you this report of the Forest Service's research accomplishments for 1972.

In addition to reporting the continuing research programs, this report gives evidence of the new approaches the Forest Service is taking in directing its research capabilities toward the critical issues in forest resource management. In keeping with that focus, more attention is also being given to improving the methods of transferring research results to the practitioners and policymakers.

Sincerely,

A handwritten signature in cursive ink that reads "John R. McGuire".

JOHN R. MCGUIRE
Chief



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U.S. DEPARTMENT OF AGRICULTURE

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FOREWORD

Forest Service research plans are coordinated through the U.S. Department of Agriculture's Office of Science and Education with research in other USDA agencies, with that conducted under the Hatch Act at land grant institutions, and with that conducted under the McIntire-Stennis Act at schools of forestry. Coordination of research with other educational institutions, private enterprises, nonprofit institutions, and other public agencies is maintained mostly through direct contact between people of these organizations and those of the Forest and Range Experiment Stations. Federal, State, industry, and university cooperation in solving mutual problems is achieved through cooperative agreements that provide for joint development and support of the research by the cooperators.

This report is arranged by research subject areas in order that the reader can go directly to the areas of interest to him. Each accomplishment is summarized in a single, short paragraph followed by an abbreviation denoting the Forest Service research unit best able to supply additional, detailed information and copies of the 1,138 publications listed. Addresses of the research units are given in the Publication List and Index.

December 1972

RESEARCH ACCOMPLISHMENTS - 1972

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I. IMPROVING THE ENVIRONMENT

A. Reducing Pollution

1. CONTROLLING SOIL EROSION

1. Terraces were found to effectively control runoff and erosion on highly erodible surface-mine benches in Breathitt County, Kentucky. Where the spoil was predominantly shale, peak floes on a terraced plot averaged 65 percent less than those on the control plot, sediment yield average 52 percent less, and total runoff average 42 percent less. Comparable figures for plots having substantial amounts of sandstone were 65, 70, and 6 percent, respectively. NE (184).

2. Slope was the principal factor contributing to soil slip erosion on mountainous watersheds in southern California, but conversion of brush to grass produced 2.8 times more erosion. In evaluating conversion of brush to grass on steep terrain, the potential hazard of increased erosion should be considered. PSW (194).

(For additional items relating to IA1 see paragraphs 365, 366, 373, 378-382.)

2. UTILIZING SOLID WASTES

3. Salty bark residues from wood industries of the Pacific States generally did not adversely affect soil microbes, and were only somewhat depressive to growth of salt sensitive plants at higher concentrations when mixed into the soil. Much of the 5 million tons of tree bark produced annually contains up to 3.5 percent salt (NaCl) as a result of exposure to sea water, but could be used for surface mulching for some salt tolerant plants. PNW (195).

3. CHEMICALS IN THE FOREST ENVIRONMENT

4. Endrin was applied to soil at rates of more than three times the maximum normally used in treating tree seed in the Douglas-fir region of the Pacific Northwest without exerting an appreciable effect on numbers of soil microbes or on ammonification, nitrification, or sulfur oxidation. Rate of decomposition of soil organic matter, as indicated by the production of CO₂, increased significantly in the presence of endrin. The relatively insignificant amount of endrin formulation entering forest soils from coated seed is believed unlikely to damage soil microbes and their activities. PNW (196).

5. Forest tree thinning workers were found to absorb arsenic from the silvicides cacodylic acid (dimethylarsinic acid) and monosodium methanearsonate (MSMA), which are used by public and private forest agencies in chemical tree thinning programs throughout the Pacific Northwest and elsewhere in the United States. Much of the chemical appears to be excreted from the body in a short time, and no evidence of continuing increase in arsenic levels over a period of more than 2 months was found. However, persons using these materials should be trained to observe all necessary precautions to minimize their exposure. PNW (207).

4. NOISE ABATEMENT

6. Our environment has become relatively noisy in many areas as a result of increasing population density and heavy dependence on mechanical devices. Forest stands in the northeastern United States were found to absorb sound at the rate of 6 to 8 decibels per 100 feet, although the actual amounts depend upon vegetation density and sound characteristics. Even though the amounts of absorption seem low, trees and associated vegetation may make the difference between a livable and nonlivable environment. NE (208, 209).

B. Improving Wildlife Habitat

1. EVALUATING AND IMPROVING WILDLIFE HABITAT

7. Deer and elk have marked seasonal preferences for certain forest habitats in Oregon. The animals feed in both grasslands and open forests during the spring, but later shift to forest habitats for food and cover as preferred forbs mature. Open forest has the greatest season-long abundance of forage, while dense forest is more important for providing cover than food. PNW (310).

8. Two dimensional phenolic extraction on chromatographic paper was discovered to be a simple and accurate method for classifying the foliage of various plant strains of big sagebrush into major palatability classes. The results of the technique were in close agreement with observed preferences by deer. The strong association between chromatographic variation and palatability suggests that this procedure may be utilized to quickly evaluate the grazing potential of any collection of big sagebrush foliage samples. INT (312).

9. Proper management of elk herds depends in part upon our knowledge of the nutritional values of foods available during the winter months when the animals are often under nutritional stress. Of 11 herbs and shrubs tested from winter elk feeding sites in Wyoming, big sagebrush had the highest digestibility. The high digestibility plus the fact that winter use by elk is less damaging to the plant than use at other times of the year suggest that big sagebrush may be an important winter elk food. RM (315).

10. The study of food habits is a major research activity in wildlife ecology, and many workers have used tame animals to acquire more exact information on food preferences. The most acceptable results for tame Rocky Mountain mule deer are obtained if the fawn is left with its mother for at least 12 hours but less than 24 hours. This time period allows the fawn the nutritional benefits of its mother's milk but exposes the fawn to the trainer before developing a fear of humans. RM (314).

11. An illustrated "Atlas of Southern Forest Game" has been published by the Southern Forest Experiment Station. The Atlas presents information on numbers, distribution, and hunter harvest of the principal game animals of our southern forests. The Atlas should prove helpful and informative to researchers, game managers, and outdoor recreationists interested in wildlife and their habitats in the South. SO (311).

12. Studies of porcupine populations are hampered by the fact that the longevity of porcupines under wild conditions has never been well established. This is because there is no proven method for aging the animals. Recovery of porcupines captured and ear-marked in 1961 in western Upper Michigan, indicates the animals have a lifespan of at least 10 years. NC (309).

13. White-tailed deer in the Appalachian Mountain, Piedmont, and Coastal Plain Provinces of the Southeast select the same type of diet seasonally although foraging in ecologically different areas. Green leaves of woody plants were the most important single item selected by deer, ranking first in frequency of occurrence and volume. The annual contribution of forbs, grasses and sedges, fungi and dried leaves combined equalled that of green leaves. Hardened woody twigs had the lowest frequency of occurrence and lowest volume of all food categories. SE (313).

(For an additional item relating to IB1 see paragraph 383.)

2. INTEGRATING WILDLIFE AND OTHER USES

14. Mixed conifer stands in the Pacific Northwest that have been clearcut, planted with pine trees, and seeded to timothy are a source of summer forage for elk, deer, and cattle. After five seasons use, growth and survival of the trees had been neither greatly harmed nor benefited by the grazing animals. PNW (318).

15. Wildlife food plants in clear-cut oak stands in the Ozarks increased severalfold compared with production in stands selectively cut. Fruit production in clear-cut stands was substantially lower than that in selectively cut stands because of the absence of overstory vegetation. This suggests that forest management needs to disperse clear-cuts in mature stands to promote maximum benefits to wildlife habitat. NC (316, 317).

16. Dependable information on changing squirrel populations is essential to effectively manage their habitat. A study of census methods showed that squirrel population trends on a 20,000-acre tract in West Virginia were measured best by personal hunter interviews to determine hunter success. Use of this information can reduce costs and improve reliability of squirrel habitat management evaluation on large forest units. NE (320).

17. The food habits of the bobwhite quail have been researched rather extensively throughout the Southeast, but little is known about the seasonal diet in the flatwoods of south Georgia and north Florida. Actually, quail diets in grazed flatwoods of south Georgia are not greatly different from those reported in other regions. Quail rely heavily on seeds of plants commonly associated with fire or mechanical site disturbance. Cultivated grains such as corn are relished by quail. SE (319).

C. Developing Opportunities for Outdoor Recreation

18. A symposium on recreation was held in October 1971 designed to consolidate and synthesize past research in forest recreation. The papers in the proceedings cover a wide range of recreation subject matter, and are aimed at meeting the needs of the planner and manager in both private and public areas of forest recreation. At the same time, each paper includes a wealth of reference material that should be helpful to anyone who wishes to pursue a given subject in more depth. NE (164).

1. WILDERNESS ECOLOGY AND MANAGEMENT

19. Wilderness managers have needed a technique to develop accurate descriptions of the natural ecosystem to guide management. A technique called systems analysis and modeling has been used to describe the wilderness ecosystem of the Boundary Waters Canoe Area in northern Minnesota. It identifies and describes the communities of the area and shows how they are related to the environment and to each other; predicts the behavior of species along environmental gradients; and predicts inter-specific association patterns. NC (135, 136).

20. A pollen diagram providing an absolute time-scale documentation of vegetation changes was prepared for Lake of the Clouds region in the Boundary Waters Canoe Area of Minnesota. Cores to get pollen samples were taken to a depth of 100 feet below the water. Carbon-14 dating demonstrated that layering in the cores was annual. The 9,349 annual layers in the 100-foot cores provide a continuous record, in absolute time, describing post glacial vegetation changes. NC (132).

21. Canoeists rely heavily on outfitters for information on the Boundary Waters Canoe Area. The information provided by outfitters is important in generating support or opposition by the users for existing or proposed management policies. Utilization of the outfitter-camper influence process could increase public understanding of the wilderness and its management. NC (133).

22. Minnesota's Boundary Waters Canoe Area is one of the most heavily used wilderness areas in the United States. To describe the impacts of increasing use on established recreation sites, area expansion, soil loss and compaction, declining tree vigor, loss of ground cover, and increased use were quantified as indicators of site deterioration. By combining these factors with amount of use and cover type, it may now be possible to develop a deterioration stage classification useful to managers. NC (134).

23. Contrary to common thinking, wilderness users are not exceptionally wealthy nor do wilderness visitors have more leisure time than most people. Wilderness, as viewed by the users, is not separate from or in contradiction with multiple use, and wilderness must be managed in order to optimize net benefits to society. INT (137).

24. Biological changes in a wilderness ecosystem due to recreational use necessitates the knowledge of how visitors themselves define excessive change or inappropriate use. Visitors to four wildernesses indicated that solitude (or low intensity of use) was an important quality of wilderness, and that littering and the visible effects of overuse or misuse were more objectionable than encounters with other visitors. A substantial proportion of the visitors seemed to have attitudes and desires that would be more suitable for roadless recreation areas than by wilderness. INT (138).

2. MANAGING THE VISUAL ENVIRONMENT

25. A study of viewer preferences found that nature scenes were greatly preferred to urban scenes. Viewers responded most favorably to scenes they could comprehend easily, scenes that promise additional information, and a variety of particular features of the landscape, such as water and paths. NC (139).

26. Dividing a regional landscape into units greatly eases the development of management goals consistent with the visual resource. This approach was evaluated in California where the Lake Tahoe Basin was divided into 11 visual landscape subdivisions. By defining visual subunits, the planners were able to objectively explore the potential scenic impacts of development and establish priorities concerning the directions of development. PSW (140).

27. Multiple forest covers can be managed in naturalistic intergrated patterns that create variety and enhance scenic quality. Three vegetation types build variety: meadow, shrub thicket, and forest. Where they come together they form natural meandering edges and graceful patterns. Land manipulations, including prescribed burning, are scenically compatible if resulting patterns imitate nature. SE (141).

28. Forest management to maintain or improve scenic quality has impact on other forest management goals. This effect was studied

by applying a scenic classification system to a 16-mile strip of highway on the Sierra National Forest in California. By conducting a scenic classification instead of relying on arbitrary rules for protection of scenery, management can be prescribed for each scenic category and management costs estimated. PSW (142).

3. SOCIOECONOMIC VALUES OF OUTDOOR RECREATION

29. In a study to evaluate the effectiveness of various antilitter procedures in two neighborhood theaters, it was found that providing monetary incentives for the appropriate deposit of litter was the most effective method. The incentive procedures resulted in the removal of 90 percent of all litter by the children in attendance. The results of this study suggest the possible utility of employing positive procedures to combat litter in other areas such as campgrounds. PNW (143).

30. Vandalism, nuisance behavior, littering, and violations of rules and regulations are major recreation management problems. Violations occur because of ignorance of, lack of understanding of, or a willingness to disregard rules. Several logical approaches are suggested for the control of depreciative acts, including better communication of rules, education programs to increase the campers awareness of the consequences of certain acts, and stricter enforcement of regulations. PNW (144).

31. Campers and campground managers subscribe to similar goals associated with camping, but they disagree about the types of activities appropriate to attaining those goals. Managers see isolation and primitive interaction with the environment as necessary; users apparently find the highly developed, structured setting of the modern campground and its associated social environment as appropriate. If the campers' perspective is the product of increasing urbanization, then a continued reflection of this influence in the modern camping scene is expected. Strategic location of a range of camping facilities will help avert problems inherent in continued change. PNW (145).

32. Expenditures by campers and other tourists are thought to be an important source of income for rural economics. In a study of families camping in New Hampshire State Parks, total expenditures by the campers varied widely by geographic location and by whether or not the park visit was a major destination or a transient stopover. Camper expenditure patterns suggest that the single goal of maximizing local area economy is a poor rationale for locating new public camping facilities. NE (146).

33. Thirty-four campgrounds on the Superior National Forest in Minnesota were used over five times as much as were others in the same area. Occupancy was related to three factors: proportion of waterfront campsites, length of time the campground had been open, and the fishing reputation of nearby lakes. Onsite interviews identified the factors affecting campground selection as: (1) fishing opportunities, (2) natural setting

(remote, wildernesslike), (3) nearness to recreation attractions (other lakes, streams), (4) recommendations of acquaintances, and (5) availability of water-oriented campsites. NC (147).

34. Rural landowners can make a profit by providing needed snowmobile services and facilities. Case studies of eight commercial snowmobile enterprises in New York indicate that a market is developing, but it is quite restricted and a potential operator should not go into the business without giving careful consideration to the capital and land requirements. NE (148).

35. Northeastern camping market during 1961 to 1967 shifted from a predominantly public-sector market to a commercial-sector market. Growth in both the commercial and the public market was positively related to proximity to water resources. Public camping market growth was associated with unsettled, heavily forested, mountainous zones, while commercial growth was associated with relatively settled, less heavily forested zones. Growth trends indicate the market will grow at a slower rate in the future. NE (149).

36. Private land leasing could play a major role in alleviating the recreation resource shortage. A study of groups and individuals leasing land for recreation in New York showed that leasing benefits both the lessee and the lessor. The lessee gains access to resources to satisfy his recreation needs, and the lessor is provided an income to help cover his taxes and assist in land conservation practices. NE (150).

4. CAMPSITE DESIGN AND MANAGEMENT

37. The deterioration of ground cover vegetation is a problem on heavily used recreation sites. In drier regions of the West, watering, fertilizing, and seeding increases ground cover on sites under an aspen overstory. On sites under coniferous stands, herbaceous ground cover cannot be established and maintained even after water, fertilizer, and seed are applied. INT (151).

38. Small, unballed tree and shrub seedlings were planted in a developed campground in the southern Appalachians to determine the suitability of supplementing existing vegetation with small planting stock. Seedling loss was high and height growth was poor, primarily because of vegetative competition and maintenance activities. SE (152).

39. Vegetation on 49 Adirondack campsites was mapped and measured in 1964 and again in 1969. Results indicate that vegetation on established, well-maintained campsites deteriorates little, even though the sites receive heavy, sustained recreation pressure. NE (153).

5. ANALYZING RECREATION RESOURCES AND USE

40. Often a method is needed to predict total visits using counts of past per-capita and total visits. While it is convenient to do this simply on the basis of the correlation coefficient printed by most regression programs, this easy procedure may produce erroneous results. It is better for the researcher to use several alternative error measures to compare the prediction models. PSW (154).

41. Among all industries in the business of outdoor recreation, ski resort owners have one of the largest capital investments. And yet few, if any, prediction equations based on the economy of the operation have been devised to help them forecast the use of a proposed resort. An approach has been developed which allows the investigator to forecast the economics of the operation by the level of use a proposed site would receive and to identify the public it would be serving. PSW (155).

42. A new computerized technique called VIEWIT for measuring the terrain visible from a given point was applied on the Black Hills National Forest, South Dakota. The areas seen from 12 heavily visited scenic points and along three proposed routes for a scenic tramway were delineated. The computer produced overlay maps that show the maximum area visible from each observation point. PSW (156).

43. Campground registration permits contain information useful to planning and specifically helpful in determining the market areas which campgrounds are serving. It is difficult, however, for managers and planners to reduce the voluminous information into useful summaries. A computerized method is now available for a quick and inexpensive summarization of point-of-origin and length-of-stay data for campground users. The method should be equally useful for public as well as private campgrounds. PSW (157).

44. Current sampling techniques for estimating recreation on land have little direct application for estimating water-based recreation use. A sampling method for estimating recreation use on large bodies of water has been developed and tested in eastern Oregon. The method utilizes data on hours of boating per person per trip, the number of persons per boat, and the number of boats per hour, and applies a simple linear regression analysis. Study results show the method provides suitably precise estimates of recreation use at a reasonably low cost. SE (161).

45. A sampling technique for estimating fishing use was pilot tested on a small trout stream on the Francis Marion National Forest in South Carolina. Utilizing a short questionnaire completed by fishermen using the stream, the technique provided precise low-cost estimates of fishing use. SE (160).

46. Surveys of wilderness visitors are valuable in wilderness management, but improved sampling methods are needed. Sampling methods involving unmanned registration stations and personal interviews of entering

groups provide the most precise estimates of wilderness use. Mail surveys are less expensive than personal interviews but lack control of sampling as with the unmanned registration stations causing incomplete coverage of the user population. Nevertheless, a registration system is worthwhile as one of the tools for wilderness-use estimation. SE (159); INT (162, 163).

47. Outdoor recreation activities are numerous and diverse which hampers their study. A study categorizing by types of five conceptually related outdoor recreation activities was developed for more meaningful analysis of outdoor recreation activities which are too numerous to consider separately. Methodological problems are discussed and theoretical models of relationships between activities and biological and social factors are proposed for future testing. PNW (158).

48. The public encounters more environmental blights driving than in any other pursuit. The development of inventory methods to measure the kind and extent of manmade alterations on the roadside landscape is the first step towards the reduction of scenic conflicts along roadways. Ground surveillance and ground photography are used effectively to record impacts within the corridor visible from the road. Aerial photography can be relied on for recording impacts on a more complete corridor including areas screened from the road by vegetation. PNW (165).

49. Statistically reliable methods exist for estimating recreation use on large areas, but they often prove prohibitively expensive. Two measures relating to recreation use which have not been stressed but which can be important to planners and managers concern the number of participants engaging in specific activities and the length of time given to these activities. These use-related measures can be employed to yield better estimates of visitor-days than purely subjective means, though not on a statistical basis. SE (166).

D. Developing Range Resources

1. EVALUATING RANGE RESOURCES

50. A system of color aerial photography and ground sampling has promising possibilities for conducting range inventories at less cost than conventional ground surveys. Large-scale color infrared aerial photographs can be used effectively to identify various shrub species and certain large forbs. Green herbage or corresponding dry weight mass can also be estimated reliably using color infrared aerial photographs. The efficiency of color infrared photos depends on obtaining photographs at the right time of the year in respect to phenology of the vegetation. RM (168, 169).

(For an additional item relating to ID1 see paragraph 380.)

2. CHARACTERISTICS AND FORAGE VALUES OF RANGE PLANTS

51. Arizona cottontop is a productive, palatable, dominant perennial grass on many southwestern semidesert ranges, but basic information has been lacking on its growth and development. This information is now available from detailed studies under natural field conditions and will be valuable for the development of management practices to use Arizona cottontop more widely in revegetation work, and for the management of the grass in native stands. RM (170).

52. Direct seedings of winterfat, a naturally occurring common shrub on semiarid ranges of New Mexico and very palatable to livestock and wildlife, have often resulted in poor stands or complete failures. Studies now show that germination and emergence of direct seeding are best with temperatures for germination between 50 to 80 degrees F. and a planting depth of 1/16-inch in moist but not excessively wet soil. This information is valuable when using this shrub for revegetating semiarid ranges. RM (172, 173).

53. Sheep weight gains and grazing capacity of spring growth of cheatgrass were equally as good as those for native bunchgrasses in southern Idaho during wet years. However, during dry years, larger weight gains, greater grazing capacity, and higher gains per acre were realized from bunchgrasses. Therefore, bunchgrasses with their extended green-feed periods and higher productivity during dry years promise greater overall gains and grazing capacities than cheatgrass. INT (171).

3. LIVESTOCK AND GRAZING MANAGEMENT

54. Clearcutting of lodgepole pine in Montana stimulates increased production of the understory vegetation for big game and livestock. Seeding of forage species in the clearcuts substantially adds to the production. To take advantage of this increased resource, big game and livestock habitat managers have needed a method to predict production before clear-cutting. Site index, a method commonly used to measure site potential for lodgepole pine growth, was evaluated as a possible method to predict understory production but failed to provide the necessary capability. INT (167, 174).

55. Southern Forest Experiment Station research results indicate that light or moderate grazing by cattle (33 and 37 percent use) does not affect establishment of planted or seeded slash pine or survival to age 5 years. Grazing had no effect on height growth of the pines to age 5. Consequently, grazing can be effectively integrated with timber production on slash pine forest lands in Louisiana. SO (176).

56. Cattle producers using the 50 million acres of commercial forest land in the West Gulf of Mexico region have needed published guides summarizing research results concerning management of the beef cow herds grazing these native ranges. This need is met by an analysis of past

research conducted on the Palustris Experimental Forest in central Louisiana. It describes prescribed rotational burning, supplemental feeding of cottonseed cake, crossbred cows, good bulls, regulated breeding seasons, and use for maximum returns of forest range investments. SO (175).

57. The subalpine zone of the Big Horn Mountains, Wyoming, is characterized by grassland parks rimmed by coniferous forests. These grasslands, together with associated meadows and shrublands, occupy one-third to one-half the 1.1 million acres within the Big Horn National Forest and are an important range resource highly prized by local stockmen. Twenty years of cooperative range research have now been summarized in the form of management guides for livestock ranges on the Big Horn Mountains and similar rangelands of the West. The report summarizes information on geology, climate, soils, and vegetation, and discusses grazing systems and range improvement practices. RM (177).

4. RANGE ECOLOGY

58. Botanists, resource managers, and others interested in the vegetation of the Black Hills of South Dakota and Wyoming now have available a revised checklist of the vascular plants of the region. The checklist gives the scientific name, botanical authority, plant family, and a life form designation for 1,759 plant taxa of the Black Hills. Also included is a discussion of the physiography and plant ecology of the area. RM (178).

5. RANGE IMPROVEMENTS

59. Growth response to application of all combinations of nitrogen (N), phosphorus (P), and sulfur (S) on four forest and three grassland soils in northeastern Oregon showed that a significant N-S interaction existed for all seven soils. For two grassland soils, a significant response to P was obtained in combination with N and S. The volcanic-ash derived soils have high yield responses to fertilization. PNW (179).

60. In a 25-year-old plantation of slash pine near Olustee, Florida, a single application of 200 pounds of nitrogen and 44 pounds of phosphorus per acre increased production of herbaceous understory to more than a ton per acre the first year, a fivefold increase. This indicates that with fertilization, a plantation suitably stocked for timber production can also be managed to produce a significant amount of forage. SE (180).

61. The most effective way to stabilize soils in a critical area is to establish plants quickly. The results of studies at Santa Fe, New Mexico, indicate that planting seeds in moist soil and applying a mulch provide near-optimum temperatures and moisture for germination. Mulching results in more moisture in the seed zone. Mulches with reflective properties have proven most effective for seeds that require relatively cool temperatures for germination. RM (181).

E. Trees to Enhance the Environment

62. Lobelia inflata L., Indian tobacco, is the main source of the alkaloid, lobeline, which is used in antismoking preparations. To aid the drug-plant buyer in determining the purity of purchased L. inflata seed, the comparative description of the seeds of L. inflata and three common lobelias of Appalachia which are not valuable has been developed. NE (965).

63. Guides for eastern Kentucky and southeastern Ohio are now available for the proper selection of white pine seed sources for Christmas trees. When white pine trees from 16 different seed sources collected in their natural range were grown for 5 years in Kentucky and Ohio, the trees of best Christmas tree quality in terms of color, form, needle length, needle retention, and growth rate came from the Appalachian Mountain region and from lower Michigan. With these proper seed sources, more profitable Christmas tree farms can be established in Kentucky and Ohio. NE (967).

64. The full value of Scots pine as a tree for the Plains has been largely overlooked because performance has been judged on relatively few and mostly unknown seed origins. An 8-year test of 36 rangewide provenances grown in eastern Nebraska showed that selected southern seed sources, with their slow growth, but dark green shoot needles make desirable Christmas trees. The very fast growth and longer needle sources of Central Europe make them useful for windbreaks, while the very yellow northern origins make attractive ornaments in the Great Plains. RM (966).

65. Because the larches combine such desirable windbreak tree characteristics as good height potential, rapid growth, moderate density, and resistance to winter desiccation, they would be a useful tree for the shelterbelt programs in the northern Great Plains. A 10-year test of 3 Siberian, 1 Dahurian, and 2 hybrid larch seed origins suggests that two of the Siberian sources from Tuvinskaya and Altaiskaya mountain provinces should be considered suitable as a seed source for future windbreak plantings. RM (964).

66. Excessive traffic noise, a form of environmental pollution, is increasing in the United States. Tests in Nebraska have now demonstrated that when properly used, trees and shrubs can be an effective means for reducing noise levels. With a wide belt of tall dense trees, noise levels can be reduced by as much as 50 percent, and even a single row of dense shrubs backed by a row of taller trees can effectively reduce noise by 30 percent. Trees, to be an effective barrier to noise, should be placed close to the area to be protected. RM (963).

(For an additional item relating to I E see paragraph 6.)

II. IMPROVING THE ENVIRONMENT AND PRODUCTIVITY

A. Improving Environmental Quality Through Fire Management

1. FIRE PREVENTION, HAZARD REDUCTION, AND PRESCRIBED BURNING

67. Individuals and employers held responsible for starting forest fires in National Forests of the Intermountain and California Regions over a 10-year period were usually local people and respected members of the community. When payments were made, individuals and employers generally paid damages less than those assessed. PSW (325).

68. The diffusion of information in an area of high incendiary forest fire incidence in the southern United States was identified in terms of three distinctly different local opinion leader roles: initiator, legitimizer, and diffuser. Knowledge of the identity of those who play each role should be a benefit to organizations conducting fire prevention campaigns. SO (326).

69. Forest fire prevention needs a resurgence at the grass roots level through more localized application of known prevention techniques. Prevention programs could be strengthened by emphasizing person-to-person contact and using existing organization structures at the local level to a much greater degree. SO (330).

70. Bulldozing, fire, and herbicide treatments were used to clear brush fields near Mt. Shasta, California, prior to planting ponderosa pine. Sprayed plots with less than 5,000 cubic feet of brush crown volume, 5 years after pines were planted, are expected to remain fairly open and present minimum fire hazard and brush competition for 25 years. A dense brush cover with loss of most pines appeared certain on unsprayed plots. PSW (321, 322, 323).

71. Fuel breaks, one approach to California's wildfire problems, should be designed as part of the preattack and presuppression inventories and the fire control planning objectives. Guidelines have been developed to aid in developing fuel breaks in the Sierra Nevada mixed conifer type. PSW (333).

72. The most effective method of breaking seed dormancy in creeping sage, a shrub that dampens fire spread in flashy annual fuels, is a soaking in gibberellic acid at 500 parts per million for 4 hours with constant agitation. A study of methods to break dormancy and improve germination was conducted because direct seedings have been failures. PSW (334).

73. Certain saltbush species can be established by direct seeding and may reduce fire hazards on fuel breaks in California chaparral. Fourwing saltbush produces the best stands and largest plants of the species tested. PSW (335).

74. Over 2 million acres of forest land are treated annually with low-intensity prescription fires in the 13 southern States. Field and laboratory studies are underway at the Southern Forest Fire Laboratory to better determine the effects of forest fuel burning on air quality. SE (327, 328, 329, 337, 340, 344).

75. Good, but very temporary, control of oak-mountain mahogany chaparral is possible with carefully prescribed fire following treatment of the vegetation with herbicides. This technique appears less damaging to the site than wildfires or less carefully controlled broadcast fires. RM (336).

76. The results of two experimental treatments, burning with weekly clipping and no burning with weekly clipping, disclosed that fire accelerated time of death, but continuous, severe defoliation was the actual cause of 93 percent mortality for little bluestem. NC (339).

77. Results of a survey of operational prescribed burns in the Lake States during 1970 are summarized. NC (343).

2. FIRE MANAGEMENT METHODS AND SYSTEMS

78. Two major national projects, Project Aero-Fire and Project Skyfire, are aimed specifically at applying new technology to fire management problems. Both of these projects will capitalize on developments pioneered in forestry research that now have the potential of fully utilizing advanced technology stemming from the space age. Never before have there been greater opportunities for this approach to fire management problems. WO (347).

79. The National Fire-Danger Rating System produces three indexes--Occurrence, Burning, and Fire Load--that measure relative fire potentials; fuel moisture, wind, and risk are the principal variables accounting for day-to-day fluctuations in fire danger. Three innovations in fire-danger rating are introduced in the new system: 1) it is solidly based on the physics of fire behavior, 2) it makes use of fuel models which account for local variations, and 3) improvements can be incorporated with a minimum of impact. RM (349, 350).

80. The 100-hour timelag fuel moisture component of the National Fire-Danger Rating System is computed from the daily moisture exchange factor and precipitation duration. The computational method is presented in tabular form for easy field use. RM (351).

81. The fine fuel moisture component of the National Fire-Danger Rating System will be adjusted according to the state of herbaceous vegetation. The adjustment is accomplished through solutions of rate-of-fire spread equations for various proportions of living herbaceous vegetation. RM (352).

82. A relationship between time-of-day and spread index for four interior Alaska stations is used to predict diurnal fluctuations in fire danger for planning fire control operations. PNW (357).

83. Of the 85,000 wildfires in Georgia from 1959 to 1968, 10 percent burned more than 10 acres each and accounted for 62 percent of the total acreage burned. Data on severity of weather, risk, and control action indicate shifting fire patterns within the State. SE (359).

84. Fire retardant delivery systems and research and development programs are traced from 1946 to the present. During 1970 the Forest Service used both helicopters and fixed-wing aircraft to deliver more than 13 million gallons of retardants to hundreds of fires. The major goal of retardant efforts is to control potentially dangerous fires at small size and to reduce the occurrence of costly and damaging conflagrations. WO (348).

85. Three different procedures are described for determining the salt content of present fire retardants: 1) for unthickened or thin, gum-thickened retardants, 2) thick, gum-thickened retardants, and 3) clay-thickened retardants. Since the effectiveness of long-term fire retardants is related to the concentration of the active fire-inhibiting salt, quality control is dependent on constantly monitoring salt content. INT (353).

86. A review is presented of currently used retardants, product evaluation procedures, application methods and types of aircraft used, conditions under which retardants are applied, mixing and pumping systems, and retardant research activities. This popular article reaches a new audience of liquid fertilizer manufacturers and applicators in hopes of generating new ideas in products and application methods. INT (354).

87. Brochure-form publication informs prospective retardant product suppliers and other interested persons of (a) the general nature of retardant research and development work conducted by the Forest Service, and (b) the procedures established in evaluating a proposed fire retardant product before it can be accepted for purchase and used on forest fires by Federal agencies. INT (346).

88. The effects of two fire retardants, diammonium phosphate and ammonium sulfate, on particulate emission and fire intensity were determined in this laboratory study. Particulate emission rate and total quantity of particulates were increased by diammonium phosphate treatment; ammonium sulfate fuel cribs had emissions similar to untreated cribs. Fire intensity was substantially reduced by both treatments. Future research on the retarding mechanisms of ammonium sulfate and diammonium phosphate could lead to the development of chemicals that catalyze glowing combustion with little flaming or effluent. INT (358).

89. A survey in the western United States determined how and why fire retardants are being used and obtained suggestions for better utilization of retardants. INT (355).

90. A computer simulation model of the fire control process is expected to provide improved efficiency in forest firefighting and fire prevention. PSW (360).

91. Wilderness fire management directions are being established for the 66,000-acre White Cap drainage in the Selway-Bitterroot Wilderness based on studies of fire history, fuels and fire potential, and plant communities. The wilderness fire study is providing inventory and planning tools needed by managers to provide for a more natural incidence of fire within the Wilderness Preservation System. INT (345).

3. FOREST FIRE SCIENCE

92. Fire in the northern environment was the topic of a symposium held in Fairbanks, Alaska, that explored aspects of wildlife in the subarctic: its relationship to the natural environment, to man's use of that environment, and to fire control actions. PNW (361, 384). /

93. Interior Alaska forest and range wildfire statistics for the period 1966-1969 are compared with the decade, 1956-1965, and the 30-year period, 1940-1969. PNW (362).

94. A Society of American Foresters' task force reviewed the role and use of fire in natural resource management as an aid to professional foresters in communicating an objective concept of fire in the forest. This task force urged all resource management agencies to commit significant research and management efforts toward understanding problems of smoke and other environmental effects of burning and alternatives to burning and to seek better understanding of fire's role in forest and range ecosystems. INT (382).

95. The natural forces operating in Montana forests which predispose them to wildfires are described, the present state of scientific knowledge of the production and dispersion of smoke from forest fires is presented, and alternative treatments of both fire and smoke in forests are discussed. INT (364).

96. Fire has always been part of the forest environment and is a natural agent for thinning, pruning, and fuel reduction. Fuel management planning and hazard reduction programs are suggested as approaches to the buildup of flammable fuels on much of the forest and range lands in the United States. PSW (385).

97. Equilibrium moisture contents are presented for common fine fuels in southeastern forests and Tobosa grass in the Southwest. SE, PSW (365, 366).

98. A theoretical analysis has been made of climatological influences on moisture characteristics of dead fuels. Three universal characteristics of dead fuels have been identified by numerical simulation: 1) reponse

of the fuel to climatological moisture-induced stress, 2) response of the outer layers of the fuel to both standard drying conditions and climatological stress, and 3) time required for a fuel to become independent of its previous moisture history. The first two characteristics provide a basis for fuels classification and the third permits evaluation of fuel moisture contributions to fire persistence and conditioning time for fuel moisture sensors. RM (372).

99. Moisture, ether extractive, and energy contents were measured for 1- and 2-year-old needles of ponderosa pine and Douglas-fir during two fire seasons in western Montana. Moisture content gradually increased during the summer. Ether extractive and energy contents were higher later in the summer. It is suggested that an interaction between moisture and extractives could contribute to crowning fires through a steam distillation mechanism. INT (381).

100. Field methods have been successfully used for inventorying fuel volumes and surface areas of logging slash and downed woody material. These estimates of physical properties are required for quantitative predictions of fire behavior. The technique is being used to inventory fuels for various fuel appraisal activities. INT (368).

101. Logging residue weights and volumes and a method of determining these are reported as well as the quantities of wood fiber which might be utilized. PNW (371).

102. For continuous thermobalance measurements on a cellulose sample kept at 226° C. for 1000 hours, a relatively simple pyrolysis model agrees with the experimental data within 1 percent over the entire range; but this agreement is significantly outside the experimental error in the measurements. Classical isothermal pyrolysis experiments provide data which adequately describe cellulose pyrolysis behavior under restricted experimental conditions, but do not permit extrapolation to other, quite different, conditions. The ultimate development of a completely consistent model should resolve the many apparently conflicting results observed through the years and permit meaningful extrapolations to more severe conditions. PSW (367).

103. Three major components of western cottonwood, cellulose, xylan, and lignin, have quite dissimilar thermograms, but all three are reflected in the thermogram of the whole wood. This independent behavior makes it quite likely that each component can be studied independently and the results used to predict its behavior in whole wood. This would greatly simplify study of the complex pyrolysis process. INT (379).

104. Cottonwood and cottonwood cellulose were treated with plant ash produced by ignition and this treatment caused changes in thermal behavior and pyrolysis products. However, the effect was not as pronounced as that resulting from naturally contained levels of minerals. This may mean that isolation of minerals by ignition produces changes which render the treatment less effective. INT (380).

105. Field burning tests in slash fuels in western Montana produced reasonably close agreement between observed rates-of-spread and predicted values. Mathematical predictions were consistently high and can probably be attributed to fuel discontinuities and the moisture content of extinction. INT (369).

106. Factors leading to the genesis of fire whirlwinds are examined under conditions of flat terrain, moderate burning conditions, and a known atmospheric temperature profile. During late summer periods, fire control forces might expect to find meteorological conditions permitting whirlwinds on less than 10 percent of the days. NC (373).

107. A tornado, causing damage to forest land along a 4-mile track, was photographed at a number of points near Elbow Lake, Minnesota. The pictures show an unusual combination of features that lend visual evidence to theoretical tornado models and such related vortex types as fire whirlwinds. NC (375).

108. A weighing system utilizing a large insulated platform supported on load cells has been designed to monitor and record the mass loss of large quantities of fuel over time. This development makes it possible to accurately record data on the mass loss rates of fuels in large free-burning fires that previously have been almost completely lacking. PSW (376).

109. Water-cooling at the rate of one gallon per hour effectively maintains temperatures of anemometers with sensitive electronic components below critical temperatures. PSW (378).

110. A new litter sampling device has been designed, fabricated, and tested. The impact sampler eliminates many of the past problems associated with determining the weight of forest litter samples. SE (383).

B. Improving Insect and Disease Control

1. LIFE HISTORY AND ECOLOGY OF INSECTS

a. Bark beetles

111. Flight activity of the mountain pine beetle is strongly influenced by air temperatures. Laboratory tests showed that flight started when air temperature was 65° F. and that sustained flight occurred at temperatures of 67° - 107° F. However, the warming influence of sunlight apparently facilitates flight at significantly lower air temperatures characteristic of higher elevations. RM (616).

112. Bark beetle population densities are commonly estimated from numbers of exit holes in the bark surface of host trees. Unfortunately, several adults may emerge through the same hole. A correction factor has been developed for estimating numbers of *Ips pini* beetles emerging from infested ponderosa pines. This will result in improved accuracy in studying and surveying populations of this tree better. PNW (627).

113. The influence of phloem thickness and the relationship of length of egg gallery to brood production of the mountain pine beetle were investigated in the laboratory. Over the range of phloem thicknesses examined, numbers of emerging adults increased linearly with increasing phloem thickness. In slabs where phloem thickness was not a limiting factor, numbers of emerging adults increased exponentially with an increase in inches of egg gallery. Thus, both phloem thickness and length of egg gallery significantly affect the production of beetles and the potential for subsequent attack. INT (573).

114. Three new species of mites inhabiting the galleries of bark beetles in North American conifers have been described and their biologies discussed. Illustrations and keys aid in identification of these associates of bark beetles. SO (584).

115. Ninety-six species of mites have been found associated with the southern pine beetle and allied scolytids beetles in an outbreak area in Allen Parish, Louisiana. Of these, four are known predators and an additional five species are suspected to attack the southern pine beetle. When abundant, these mites could be instrumental in limiting beetle populations. SO (620).

116. The inner bark lining the margins of lightning wounds is a fertile habitat for growth of microorganisms. A number of bacteria and yeasts are frequently encountered during the first 3 weeks following injury. To date, none of these microorganisms have produced substances that attract southern pine beetles. This finding supports the hypothesis that the first beetles attack lightning-struck pines at random rather than in response to microorganisms infecting the injured trees. SO (603).

117. Patterns of emergence of the mountain pine beetle attacking ponderosa pine in the Black Hills have been determined. The numbers and rates of emergence varied with aspect and height on the tree trunk. This information properly quantified, will permit more adequate evaluations of populations and related control decisions PNW (630).

118. A nematode, Omemeeaa maxbassiensis, was found inhabiting galleries of the bark beetle, Leperisinus californicus, in green ash. This new bark-beetle associate has been described and illustrated. It may be an important factor in limiting populations of this insect. RM (613).

119. The characteristics of diseased elm trees and the patterns of attack by the elm bark beetle, Scolytus multistriatus, have been analyzed in Yugoslavia in a study financed under PL 480. The severity of attack varied

significantly between trees and stands. In all-aged, mixed stands, mortality ranged from 0 to 47 percent, this suggested that a diversity of factors influenced the course of the disease. By felling trees with a certain beetle attack density, setting up trap logs, and treating cut material with chemicals, populations of elm bark beetle were reduced thereby avoiding a potential epidemic. WO (612).

b. Defoliators

120. Similarities in the seasonal growth pattern of ponderosa pine and incense cedar enabled entomologists to determine impacts of the pine needle sheathminer. This defoliator feeds extensively on ponderosa pine. Since cedar is immune to attack, the growth reduction in ponderosa pine due to insect injury can be accurately estimated by comparing growth in the respective species during outbreaks. RM (638).

121. Nearly mature larvae of the jack-pine budworm commonly drop from their host tree when disturbed. Many of the dislodged larvae are killed by predators. Studies show that mass drops may result in reduction of larval and pupal population densities up to 75 percent. NC (606).

122. Normally the western hemlock sawfly feeds on foliage produced during the previous year (a situation that arises, but when sawflies increase in number they feed on current year's foliage). Sawflies fed on young foliage produced in the current year suffered a 65 percent reduction in survival of females, a 10 percent reduction in males, and a 26 percent reduction in egg laying of surviving females. This selective effect on females may account for this sawfly's apparent inability to reach outbreak proportions. PNW (602).

123. In a cooperative study by FAO sponsored in Colombia, a looper, Glena bisulca, was found to be the cause of serious defoliation and death of planted cypress. Tree mortality occurred primarily on flats and in drainages. It was recommended that such areas should be planted with non-susceptible tree species. SE (590).

c. Shoot- and tip-feeding insects

124. Development of the European pine shoot moth in a Michigan planting of red pine occurred progressively later in each of 5 successive years. This trend was believed to be due to habitat cooling as the trees grew larger. Insect development was more advanced on adjacent smaller trees. These findings are further evidence of the effects of tree size and crown density on microclimate and related variation in rates of insect development. NC (617).

d. Sucking insects

125. Control of alternate host plants leads to control of the Saratoga spittlebug, a serious pest of red pine. Reduction of sweet-fern to the point

where it covers less than 25 percent of the ground keeps spittlebug populations at subeconomic levels. NC (607).

126. The potential damage of the Saratoga spittlebug to red pine can be predicted by estimating the percentage of ground occupied by sweetfern and that occupied by other plants that serve as alternate hosts. A simple graph has been developed for the land manager to use in rating the potential damage by this insect. NC (649).

127. The tuliptree scale is a serious pest in Pennsylvania. An effective means of augmenting natural control of this pest has been developed. A 4-inch wide band of sticky material--not a poison--is placed around the tree trunk. It bars access of ants to the tree crown when they interfere with native parasites and predators. Exclusion of ants increase the effectiveness of natural enemies of the scale by as much as 50 percent in a single year. NE (588).

128. A device for collecting the honeydew excreted by scale insects has been developed and successfully used under a wide variety of field conditions. The device and method are being used to estimate scale insect densities and the probable damage to trees, shrubs, and annual plants. NE (580).

e. Seed and cone insects

129. Annual cone crops and associated insect damage vary widely in seed-production areas of red pine. Cone crops fluctuate almost unpredictably from year to year. Sixty-six percent of the variation in cone damage is associated with variation in cone abundance. This information, coupled with the fact that insects attacking cones of red pine are almost entirely dependent on red pine cones for both food and reproduction, means crop size is a primary determinant of the rate of change in numbers of cone insects. NC (615).

130. Control of the pecan weevil depends upon distinguishing and quantifying insect-infested seeds. In the past, identification of weevil-inhabited nuts was almost impossible because surface damage indicating that a weevil was present was indistinguishable from other kinds of damage. The identifying characteristics of weeviled nuts have been described and illustrated, so that it is possible to identify them in time to decide on the need for control. NE (589).

131. In a North Florida seed orchard nonlethal damage to female conelets of slash pine by a thrips, Gnophothrips fuscus, resulted in mature cones having areas of sunken, deformed cone scales. Damaged cones were significantly shorter and they yielded fewer total seed and fewer filled seed per cone. This is the first report of such damage by thrips to female slash pine strobili. SE (586).

132. A number of economic and biological factors must be considered in evaluating losses caused by insects in slash pine seed orchards.

Included are: tree and seed values, expected yields, expected losses of seed due to insects without a control program, and the effectiveness of control method. Knowledge of clonal productivity and susceptibility to insect attack also provides for more efficient and effective control of insects that damage cones and seeds. SE (585).

133. Collections of mature cones disclosed the occurrence of seed-worms in three pine species growing in the Mid-South. Two species of Laspeyresia were found: one, L. ingens, was essentially limited to loblolly pine; the other, L. toreuta, occurred in all three pines but was much more prevalent in loblolly pine. Cones of Virginia and shortleaf pine were infested to a lesser degree. SE (591).

134. The Nantucket pine tip moth was found to be a major enemy of young, first-year conelets of shortleaf pine. Symptoms of attack have been illustrated and discussed. In 1968 and again in 1969, 22 percent and 31 percent of the first-year conelets of shortleaf pine were lost because of feeding by the Nantucket pine tip moth. The tip moth caused only minor mortality of conelets of loblolly pine. Late-season attacks by the tip moth on overwintering shoots and buds did not preclude development of female flowers the following spring. Guidelines have been prepared for the proper timing of chemical control in seed orchards. SE (652, 654).

135. A bibliography has been published that contains literature and processed reports through 1970 on insects known to be associated with the destruction of cones and seeds of North American conifers. The 719 citations are cross-referenced by tree and insect species. This compendium will guide managers of seed orchards and researchers to literature pertinent to their problems. SE (574).

f. Wood-products and boring insects

136. That the eastern subterranean termite selectively eats the softer or less dense early wood of coniferous woods is a familiar observation. Studies using diffuse-porous hardwoods showed that feeding by termites decreased as wood hardness increased. A similar relationship was found between loss in weight due to feeding by termites and specific gravity of the wood. Therefore, hardness and specific gravity must be taken into account when the resistance to termites of chemical extractives from woods are being studied. NC (577).

137. Species of termites differ widely in their response to humidity. Knowledge of their behavior under various humidities is of great importance in culturing each species in the laboratory. It also helps explain marked differences in survival of worker and soldier termites. WO (632).

138. Stain and decay are now shown to be associated with galleries of the carpenterworm in three species of southern hardwoods. SO (634).

139. Damage by insects leads to a rejection of from 3 to 13 percent of the stave blanks for bourbon barrels produced by mills in Ohio. This is a conservative loss estimate, since the mill operator also rejects infested trees, logs, and stave bolts before processing. An illustrated guide has been developed to aid the mill operator and stave buyer in identifying the types of insect injury leading to these losses. NE (579).

140. The Columbian timber beetle causes a serious degrade of hardwood lumber. Studies in Georgia have shown that three generations of this insect develop each year and that adults overwinter on the host tree. This information will be useful in developing both chemical and cultural controls for this insect. SE (622).

141. The flag-worm defect caused by the Columbian timber beetle is generally considered a serious defect to hardwood lumber. Values and uses are substantially reduced. However, the potential market value of this insect-caused defect as a decorative wood product has been studied. If a strong market for wormy paneling, furniture, and specialties could be developed, it would provide a lucrative outlet to landowners who own millions of otherwise low-quality trees. SE (621).

142. A borer, Saperda inornata, attacks the small stems and branches of trembling aspen in Michigan. The complete biology of this beetle and its impact on the host have been worked out. The complete biology of another hardwood borer, Obereaa schaumii, in trembling aspen in Michigan and Wisconsin has also been determined. This information will be useful in developing and evaluating controls for these insects. SE (623, 624).

143. The locust borer is a serious problem, particularly where black locust has been extensively planted for land reclamation. First-year attacks by this borer were found to be randomly distributed. Attacks tended to be more concentrated during the second year. In the third year, attacks were found to be aggregated in one area and randomly distributed in another portion of the general infestation. This attack pattern affects control treatments and the possibility of overlooking some infested trees when treating an area. NE (650).

g. Root and root-collar feeders

144. Six genera of white grubs occur in pine plantations in Wisconsin and Michigan, but only those of the genus Phyllophaga are important destroyers of seedlings. Control of white grub was recommended in the past when counts reached 0.5 grub per cubic foot of soil. The finding that grubs at this frequency cause up to 40 percent mortality of seedlings by the second growing season after planting leads to the conclusion that control should be started at lower population levels. NE (594).

145. The pales weevil, pitch-eating weevil, and Pissodes spp. are all important pests of seedling and young sapling pines in the South. Recent studies in North Carolina and Florida have helped to explain the

circumstances under which these weevils attack pine reproduction in the Southern Appalachians and in the Deep South. Species in the population of weevils differed markedly in each general area. These findings should lead to more effective management to minimize impacts of these tree killers. SE (636).

146. The pales weevil is very destructive to young pines planted on recently cutover forest land. Chemical controls, while effective, may soon be withdrawn from general use. Several alternative methods are proposed to control this threat to regeneration. SE (641).

147. Damage by the pine root-collar weevil is least in red pine plantations in cooler areas of northern Michigan, and damage decreases with distance of the host from the nearest infestation. Three hazard zones based on areal patterns of temperature have been suggested. It is recommended that planting in the high-hazard zone should be at least one mile from an infestation. In the medium zone planting should be at least one-half mile away to insure minimal damage. The only restriction for the coolest zone of low hazard was to refrain from planting red pine near a stand of Scotch pine because of its susceptibility. NC (608).

h. Mathematical models

148. Mensurational studies of forest growth and yield including losses due to insects often employ a mathematical model or a set of equations to describe changes in stand parameters over time. In the past, the individual equations in the model have been fitted one at a time by the method of least squares, but this method of estimation is not entirely satisfactory. A method of handling a forest growth and yield model as a system of equations has been developed, in which all coefficients in the model are estimated simultaneously. The technique involved is well known and widely used in econometrics, but it had never been applied before to the analysis of forest stand dynamics and insect impacts. NE (600).

149. Researchers studying populations of insects and their impacts must commonly develop an appropriate linear regression model from a large amount of data. The regressions to be calculated for even a few independent variables can become too numerous to handle conveniently by conventional methods. A new computer program enables the researcher to screen all possible combinations of his independent variables with relative ease. The program calculates coefficients of determination for all possible combinations of up to 20 independent variables. NE (595).

i. Miscellaneous

150. Adults of a fly, Pholeomyia comans, have been found to enter the nests of the destructive town ant. Biological studies show that the adult lays eggs in the underground cavities where the developing maggots feed on decaying plant material and refuse deposited by worker town ants. This fly does not affect the town ant population. SO (619).

151. Insects damage the trees and shrubs planted throughout the Great Plains to protect crops, soil, and livestock; to provide for wildlife habitats; and to provide noise abatement, beautification, and privacy. These introduced plants support tree pests which could not otherwise exist in the region. An illustrated key to 226 species of insects will aid in identification of potential insect pests and damage by them. RM (637).

152. Insects that damage five genera of important browse plants have been identified. This information will permit range scientists to measure and assess the impact of these insects on the range resources and provide a useful reference for future surveys. INT (627).

153. A survey of the forest insects attacking Caribbean pine in north-eastern Nicaragua was sponsored by FAO in the spring of 1971. The Nantucket pine tip moth and two engraver beetles, Ips calligraphus and I. cribicollis, were the most important species found in this area. Other damaging insects were identified, and future actions were recommended. SE (651).

2. INSECT PHYSIOLOGY, NUTRITION, AND REARING

154. A rearing technique that approximates field conditions was developed for the pales weevil. Bolts of loblolly pine were buried in screened beds of soil in the greenhouse; others were buried with ends exposed in cages in the field. Adult weevils were introduced into the enclosures. Associated organisms, weights, sex ratios, and behavior of weevils showed the weevils reared in the greenhouse are comparable to those collected in the field. SE (669).

155. The lipids found in phloem of loblolly pine, particularly the neutral lipids, were fractionated and bioassayed to determine whether they would stimulate feeding by the pales weevil. The natural stimulus provided by fresh phloem evidently was reduced by the fractionation treatment. However, significant feeding occurred in response to the fraction whose principal constituent was Beta-3-sitosterol. Results also indicated that substances associated with the sterols may play a role in inducing feeding. SE (682).

156. The effect of adding an emulsifier to an artificial diet was evaluated for larvae of the pales weevil. Hypothetically, the improved dispersal of fat-soluble ingredients in an emulsified aqueous medium should lead to improved growth of larvae. Results suggested that the emulsifier did improve the diet. SE (681).

157. Attractants are responsible in part for the aggregating behavior of the smaller European elm bark beetle under natural conditions. Virgin female beetles when tunneling in the bark produce a strong attractant. More beetles of both sexes attack infested bolts of elm in response to this attractant than to any other experimental treatment. Since a few beetles are also attracted to bolts of elm either uninfested or infested with male

beetles, odors from the elm are also involved. Thus, both insect-and host-produced chemicals may have to be used to trap the beetle for control purposes. NE (672).

158. Rearing individual larvae of the smaller European elm bark beetle in the laboratory is difficult and costly; yet considerable numbers are needed for studies of parasites and other experimental purposes. Improved techniques have permitted continuous rearing of 10 generations of bark beetles on two different media. A special medium was needed for oviposition and rearing of young larvae. No apparent change in behavior or physiology of the beetles was noted after the 10 generations of continuous rearing. NE (667).

159. Techniques have been developed to force overwintering larvae of the European pine shoot moth to emerge from infested shoots and to prevent contamination of rearing dishes by molds. Forced emergence avoids the need to dissect shoots and enhances survival of insects. Use of these techniques enables entomologists to rear large numbers of insects needed for identification of the sex attractant or for production of parasites. PNW (661).

160. Male European pine shoot moths were used to develop a reliable bioassay for attractants extracted from adult females. The incidence and type of male sexual responses depended upon the quantity of extract and the length of time males were preconditioned with high illumination. A quantity of pheromone equivalent to only 0.005 to 0.01 females induced a response by the males. Repeated exposure to the pheromone rapidly decreased the response. PNW (664).

161. A histological study was conducted to determine the effects of tepa, a sterilizing chemical, on male pupae of the eastern spruce budworm. An increase in protein concentration occurred in the fat body and testes of male insects treated with tepa. Tepa evidently affected the cells' ability to regulate levels of hormones or metabolism of proteins, or both. Critical changes in mature sperm also occurred. NC (655).

162. Jack-pine budworm larvae, treated with radioactive phosphorus-32 as a tracer, were released on the ground at various distances from a plantation of jack pine. Recapture 24 hours later showed how recovery decreased with increasing distance from the host trees. This information will be useful in understanding and predicting dispersal of larval populations. NC (658).

163. Larvae of the elm spanworm fed on hickory foliage developed faster than on oak. The adults were also larger and laid more eggs than those developing on oak. Concentration of soluble carbohydrates, free amino acids, and 11 major inorganic constituents differed in juvenile and mature leaves of pignut hickory and southern red oak. Undoubtedly, these differences contribute directly and indirectly to the behavior and development of this defoliator. SE (663).

164. Yellow and blue chromoproteins color the fluids in the body of larvae of the western spruce budworm. These pigments contributed to the primary coloration of budworms. Differences in concentration of the pigments may indicate qualitative differences between budworm populations and may be useful as a marker trait. PNW (676).

165. Lipids in southern lyctus beetles increase quantitatively during larval development and are utilized during the transformations from larva to pupa to adult. Larvae lacking these lipids fail to develop. SO (670).

166. Injection of a juvenile hormone analog into the western spruce budworm inhibits the shortening of certain internerve connectives during the metamorphosis of the nerve cord. This inhibition is related to the stage of development of the insect at the time of injection. PSW (677).

167. Neuromuscular studies on the wax moth have shown that bromolysergic acid diethylamide (BOL-148) when injected into larvae, produces a reversible paralysis of the body wall. Nerve and muscle electrical activity remains unaffected during paralysis. It is concluded that the drug blocks neuromuscular transmission in this insect. SE (656).

168. Insect electro-antennogramma (EAG's) are becoming increasingly useful in research on sex and host attractants. Pitfalls in the use of this technique and in the interpretation of EAG data must be recognized and avoided. SE (657).

169. Males of the cone moth, Dioryctria abietella, respond to a crude extract from the abdomens of females. Flight responses of males to this sex attractant, mating behavior, and mating periods have been worked out under laboratory conditions. This information will have application in the management of the cone moth in southern pine seed orchards. SE (665).

170. Adult town ants leave a trail of pheromone which is followed by foraging ants in the colony. The major volatile component of the trail-marking substance has been identified as methyl 4-methylpyrrole-2-carboxylate. When synthesized, this chemical may be useful for trapping this pest. SO (683).

171. Both sexes of the western pine beetle are attracted by a pheromone produced by female beetles. This response is enhanced by myrcene a terpene constituent of the host tree, ponderosa pine. Myrcene itself is not attractive. This synergism produced by the combined chemicals contributes to the attraction of masses of beetles to host trees. PSW (660).

172. The fine structure of the fungal tube (mycangium) and the associated gland cells of the southern pine beetle have been described. Chemicals secreted by the gland cells are essential to the symbiotic relationship between fungi maintained in the tub and the beetle. Similar structures and fungal associations occur in other destructive bark beetles such as the western pine beetle. SO (668).

173. Male engraver beetles, Ips grandicollis, initiate attacks on weakened loblolly pines in response to olfactory stimuli. Volatile terpenes emanating from the host phloem cause this attraction. Host attractiveness is dependent on the qualitative and quantitative composition of terpenes which, in turn, are related to the physiological condition of the host. SE (684).

3. BIOLOGICAL CONTROL OF INSECTS

a. Invertebrate parasites and predators

174. The mite Pyemotes parviscolyti is carried on the bark beetle Pityophthorus bisulcatus. It attaches itself to all stages of the insect except the adult. It does not injure the bark beetle directly, but heavy infestations may prevent mating and/or flight of the beetle. SO (698).

175. Dendrosoter protuberans, recently introduced from France, may have great potential as a parasite of the elm bark beetle. Mass rearing and biological studies underway in the United States will determine the effectiveness of this species alone and in combination with native parasites. NE (690).

176. Bracon politiventris is an important parasite of the western spruce budworm in Colorado. Studies have been made of the life history, habits, and host-searching behavior of this natural enemy. Each female wasp attacked and paralyzed about 10 budworm larvae in their feeding sites and deposited about 100 eggs externally on the surface of each budworm. RM (695).

177. In Alaska, western hemlock looper pupae are attacked by eight species of ichneumonid parasites. Four species make up 97 percent of the parasites reared from host material. Apechthis velox occidentalis is the most common parasite. Means for identifying these parasites and notes on their biology are summarized in this paper. PNW (704).

178. A key to the diagnostic features of the subfamilies of Ichneumonidae has been prepared. This will help entomologists in determining the subfamily in which adult ichneumonid parasites of forest insects belong. PNW (705).

179. Length of life, egg-laying capacity at different age intervals, and effect of light intensity on host-finding behavior of the parasites Apechthis ontario and Itoplectis quadricingulatus have been determined. Numbers of hosts killed and parasite progeny produced were criteria used to compare single-species and mixed-species performance. Results indicate it is best to introduce all the pest's primary parasites rather than to restrict importation to a preselected single species. PNW (701).

180. A survey in the Piedmont of North Carolina indicated that parasites and predators of the southern pine beetle destroyed 24 percent of the brood. Woodpeckers and the insects Thanasimus dubius and Scolopcelis mississippiensis were the most effective predators, while Roptrocerus xylophagorum and Coeloides pissodes were the principal parasites. SE (697).

181. Larvae of the fly parasite, Medetera aldrichii, enter galleries of the mountain pine beetle through beetle entrance holes. The fly larvae complete their development near beetle-created openings that lead from the galleries to the exterior. These larvae are thought to cause a major share of the beetle mortality that occurs between August and the following May. RM (702).

182. Between 1961 and 1965, 15 species of predators from India and Pakistan were released in North Carolina to determine their effectiveness in controlling the balsam woolly aphid. Recoveries to date have not demonstrated that any of the predators have become established. Lack of establishment is attributed largely to differences in climate between the old and new environment and to poor prey acceptance on the part of predator larvae and ovipositing adults. SE (685).

183. The development of mass-rearing techniques is a vital part of biological control programs. Studies at the Corvallis, Oregon, laboratory reveal that host pupae placed in plexiglass templates are readily accepted by parasites. This technique will find application in mass-producing parasites for release in forest insect outbreak areas. PNW (700).

b. Vertebrate predators

184. Predation by woodpeckers is an important natural control for trunk borers in southern hardwoods. Recent studies show significant predation of fourteen species of trunk-boring insects in Mississippi. Predation is greatest during January and February in trees less than 6 inches in diameter. SO (703).

c. Insect pathogens

185. The balsam woolly aphid is affected by a fungus disease caused by Fusarium nivale. Preliminary observations have been made on the occurrence and symptomology of this disease in North Carolina. SE (688).

186. The microflora of healthy adult and larval stages of the southern pine beetle included the bacteria Aerobacter aerogenes, Alcaligenes faecalis, and Serratia marcescens and the fungi Aspergillus sp. and Penicillium sp. Seven of the organisms recovered have been found in diseased beetles in other studies. SE (696).

187. Specific techniques, production figures, and costs have been determined for mass propagating the viruses of the European pine sawfly and the gypsy moth. Protocols for safety tests must be accepted by EPA before adequate safety data can be obtained to support registration of the virus for operational use. NE (691).

188. Strains of different serotypes of Bacillus thuringiensis may be equally effective against the gypsy moth. This suggest that efforts to find new potent strains of Bt should not be limited to a specific serotype. NE (687).

189. Diseases have a significant effect in altering gypsy moth population numbers. The disease complex varies widely between population types. Noninfectious diseases may play an important regulatory role in natural populations. NE (699).

190. Sparse populations of gypsy moth are more significantly affected by parasites than are dense populations. In dense populations, viral infection represents the primary mortality factor, while it is virtually nonexistent in sparse populations. The isolation of pathogens that can be used as biological control agents, and the development of techniques for forecasting disease incidence in gypsy moth populations are the ultimate goals of this research. NE (686).

191. Blood cells of the gypsy moth can be maintained in live culture apart from the insect. These cells support live virus when infected blood is added to the culture. Production of gypsy moth virus by this procedure would eliminate the present requirement of maintaining large colonies of insects for virus production. NE (693).

192. Elimination of insect debris and undesirable microorganisms in crude virus suspensions is required for safety tests and field evaluations of efficacy. A procedure has been developed for cleaning large volumes of virus material for these purposes. NE (694).

193. Two distinctly different nuclear-polyhedrosis viruses occur in the Douglas-fir tussock moth. Knowledge of the occurrence and development of these viruses in populations of the host insect is needed for evaluation of their effectiveness as microbial control agents. PNW (689).

4. CHEMICAL CONTROL OF INSECTS

a. Insecticides

194. Seventeen analogs of dimethoate were prepared and tested against mice and houseflies. While most of the compounds investigated were highly toxic to mice, only compounds which were N-mono-substituted showed insecticidal activity. SE (712).

195. Significant differences in the ecosystems and in crop and/or resource values involved have resulted in different insecticide use patterns employed against forest and agricultural pests. This has had a tangible effect on contamination problems in the respective environments. Various characteristics and amounts of different insecticides may be utilized in an integrated control approach. The potential for using Zectran in managing spruce budworm populations is discussed as an example. NE (731).

196. Laser holography has been used to study the characteristics and behavior of insecticide aerosols. It allowed direct three-dimensional stop-action study of spray particles as they landed on western spruce budworm larvae and their silk webbing. The hairs of this insect effectively intercepted small spray droplets. PSW (725).

197. Drift from herbicides and insecticides poses a potential hazard to sensitive nontarget organisms and increases residue problems in plants, animals, air, and water. The potential drift hazard is greater from aerial application of herbicides than from insecticides because of the chemical nature of herbicides and their patterns of use. The quantity and extent of drift can be reduced by regulating spray formulation, rate of application, atomization, and method of application and by giving proper consideration to the role of weather in affecting spray behavior. PNW (720, 721).

198. The effectiveness and safety of aerial applications of pesticides depend on obtaining maximum target coverage with minimum concentrations and spray volumes, and by reduction of drift into nontarget areas. Improved aerial application technology will lead to more efficient target coverage and, in turn, a more favorable cost-benefit ratio for pest control programs. PNW (722).

199. Large numbers of orange tortrix, Argyrotaenia citrana, larvae reared on an artificial wheat-embryo diet were topically treated with four insecticides. The test compounds, in descending order of toxicity, were pyrethrins, Zectran, DDT, and malathion. PSW (727).

200. A water-soluble salt of Zectran was applied topically to the dorsal surface of individual body segments of the western spruce budworm. Mortality was greatest when application was made to the head or seventh abdominal segment. PSW (728).

201. Zectran was tested as an aerosol against the larvae of the California oakworm, Phryganidia californica, the adult of a primary parasite of the oakworm, Itoplectis behrensii, and the adult of a hyperparasite, Dibrachys cavus. The increasing order of susceptibility to the insecticide was oakworm, Itoplectis, and Dibrachys. To minimize this adverse effect on parasites, oakworms should be sprayed when they are in the 3rd and 4th larval stages. PSW (726).

202. Fourteen insecticides were evaluated for contact toxicity to larvae of the pine butterfly in a laboratory spray chamber. All candidate materials except trichlorfon were more toxic than DDT. Several insecticides might provide adequate control of this defoliator at application rates of less than 1 pound per acre. However, field tests are still needed to establish the minimum effective dosages of the most promising compounds. PSW (717).

203. Ten insecticides were tested in aerosol form against adult needle miners of the genus Coleotechnites. Pyrethrins were about six to seven times more toxic than malathion, the insecticide currently registered for use in suppression of needle miner epidemics. The relatively higher toxicity of pyrethrins, together with the development of a stabilized formulation, make them promising candidates for practical control. PSW (718).

204. Forty insecticides and one antifeeding compound were tested against pandora moth larvae in a search for safer candidate chemicals for field trials. Twenty-one insecticides were more toxic than DDT. The pyrethrins formulation was 288 times more toxic than DDT. PSW (716).

205. Thirteen insecticides were tested against the California five-spined engraver and six were tested against the western pine beetle to find alternatives for lindane. Five compounds--Zectran, Dursban, malathion, dichlorvos, and pyrethrins--showed promise for further research and field testing. PSW (715).

206. Bioassays were conducted to determine the effects of storage procedures and dose on the degradation and effectiveness of dicrotophos in controlling the smaller European elm bark beetle. Results suggested that dose of dicrotophos was the most important factor affecting beetle feeding. NE (707).

207. Twigs were taken from American elm trees sprayed with methoxychlor by mistblower and helicopter to determine residue levels and treatment effectiveness against the smaller European elm bark beetle. Spray deposits were higher and more homogeneous for mistblower-treated trees than for helicopter-treated trees. The mistblower treatments, correspondingly, were more effective against the beetle. NE (706).

208. A spring application of 40 grams of phorate granules raked into the soil effectively protected individual young ponderosa pines from damage by western pine tip moth for two growing seasons. Dimethoate sprayed in the spring and summer provided immediate control of the tip moth during the first generation but not the second. These findings suggest that dimethoate should be applied at the time of larval emergence. More frequent treatments will be required than with phorate. RM (729).

209. Eight systemic insecticides were tested against the Saratoga spittlebug. Applications of granules of baygon, temik, furadan, and phorate provided 94 to 100 percent control. Baygon appeared to be the best and "safest" chemical. NC (732).

210. Disulfoton and Monitor R are absorbed and translocated from the roots of loblolly pine seedlings upward to the new terminal growth. Bio-assays with pales weevils revealed that Monitor was more effective during the first 15 days, while disulfoton was more effective during the 30- to 90-day period. These compounds deserve detailed study to determine the mechanisms of absorption and translocation and possible use for weevil control. SE (730).

211. Insecticides added to concrete at the time of mixing have prevented tunneling by subterranean termites over or through cracks in the concrete under field conditions. Laboratory studies showed that the termites died when they were placed directly on dieldrin-treated concrete. SO (708).

212. Laboratory tests indicate that the Formosan subterranean termite and two species of native subterranean termites differ in their susceptibilities to aldrin, chlordane, dieldrin, and heptachlor in soil. The Formosan termite is able to tube through soil containing higher amounts of insecticide than the native termites. Also, the native species usually succumb more rapidly than the Formosan species when placed directly on treated soil. SO (709).

213. Analyses of residues and degradation products of technical heptachlor weathered 4 years in an Oregon soil revealed an unknown component in layers below the soil surface. Analyses showed the unknown to be 1-hydroxy-2, 3-epoxychlordene which had not been reported previously as a degradation product in heptachlor-treated soil. SO (710).

214. Numerous termiticides have been under study for many years in southern Mississippi. Of these, aldrin, chlordane, dieldrin, and heptachlor applied at several concentrations and rates still remain effective after 17 to 21 years. SO (714).

215. Dicrotophos was injected as a liquid into the trunks of mature slash pine trees to control several seed and cone insects. Direct injection into bored holes gave consistently better control. This method also had the advantages of permitting individual crop-tree treatment and a single insecticide application each year to control most of the known major seed-destroying insects affecting slash pine. SE (723).

216. Tests were conducted to determine if a flower thrips, Gnophothrips fuscus, and southern cone rust could be controlled with mistblower applications of the fungicide ferbam combined with either malathion or heptachlor. The feasibility of controlling southern cone rust with mistblower applications of ferbam was not established but thrips control was obtained. SE (711).

b. Natural products

217. Pyrethrins and pyrethroids have long been used as insecticides. However, their instability when exposed to air and light, as well as their

high costs, have prevented large-scale use in agriculture. The combination of an antioxidant and an ultraviolet screening agent in a mineral oil formulation stabilizes pyrethrins for at least 4 hours thus permitting their use in control of some forest insects. PSW (724).

218. Laboratory tests have been conducted on stabilized pyrethrins to provide data necessary for planning field trials against the western spruce budworm. Results indicated that only slight residual activity can be expected from the stabilized pyrethrins. Reliance for control must therefore be placed principally on direct contact by the spray droplets. PSW (719).

5. SILVICULTURAL AND MECHANICAL CONTROL OF INSECTS

219. Losses of lodgepole and whitebark pine due to the mountain pine beetle were compared in study areas within two mixed species stands at high elevations. Results suggested that the beetle tends to prefer the tree species in which it developed. Moreover, mortality of the insect in the host species was different than that in another tree species. This information has direct implications for silvicultural manipulation of stand composition to minimize losses. INT (733).

220. The California risk-rating system was tested on ponderosa pine in western Montana to determine the classes most frequently killed by Dendroctonus beetles. Almost four times more high-risk trees were killed than other trees in the stand. Recognition of these trees permits selective removal and a minimizing of beetle-caused tree mortality. Such selective cutting is especially important in maintaining areas where esthetic values are high. INT (734).

221. Severe tree killing by the mountain pine beetle is an increasing problem in older, second-growth ponderosa pine stands of Oregon and Washington. Excessive competition between trees favors the occurrence of beetle outbreaks. This indicates that thinning of dense stands of ponderosa pine has promise as a silvicultural method of preventing outbreaks of this insect. PNW (735).

6. HOST RESISTANCE TO INSECTS AND TREE PHYSIOLOGY

222. Scotch pines grown from seed collected at different locations in Europe and Asia were exposed to the pine root collar weevil in Michigan. Mortality due to the insect was least for varieties from western and southern Eurasia (Scotland, Spain, southern France, Italy, Yugoslavia, Greece, Turkey, Georgian USSR) having a moderate growth rate, and highest for rapidly growing varieties from central Europe. NE (741).

223. Small differences in relief on a flatwoods site were related to soil-water regime and diameter growth of 40-year-old loblolly pines. The soil-water parameter and tree growth responses indicate an unstable environment on flat sites that probably affects tree rooting and, in time, susceptibility to bark beetle attack. Results of this study partially explain the development of tree decline on flat sites, the very drastic loss in oleoresin exudation pressure in trees on such sites during drought periods, and consequent increased susceptibility to the southern pine beetle. SO (738).

224. Oleoresin exudation pressure (OEP) of loblolly pine was highly correlated with relative water content (RWC) of needles and the water potential (WP) of twigs measured by the pressure chamber technique. Oleoresin exudation flow was correlated with RWC and WP and not at all with OEP. The manometric technique of measuring OEP is a convenient and inexpensive way to estimate water stress in large loblolly pines. SO (737).

225. Periodic outbreaks of the fir engraver beetle have resulted in severe depletion of true fir stands in western North America. Endemic populations have caused continuous, less spectacular loss. Recent research has shown that populations of the insect in flight may be trapped or diverted to reduce such losses. PSW (736).

226. An accurate procedure has been developed for quickly approximating monoterpene composition in trees being studied for resistance to bark beetle attack. This procedure is about three times as fast as the standard technique. PSW (740).

7. SAMPLING AND SURVEY METHODS

227. Radiographic techniques have been perfected to detect and count the parasite Agathis pumila in host larvae of the larch casebearer. Large parasite larvae have been detected in host insects with 100 percent accuracy, but the smaller larvae cannot be detected consistently. INT (743).

228. The development of adequate sampling methods requires knowledge of the target insect's habitats and behavioral activities. The egg-laying habits and patterns of the fall cankerworm, and the number of eggs that constitute a mass have been determined and form the basis for an egg mass sampling method. NE (748).

229. A method has been developed for rapidly estimating the population levels of European pine sawfly egg clusters or larval colonies in young red and Scotch pine plantations. Populations are classified from the percentage of trees infested with sawflies. Sample data combined with a knowledge of the insect's damage potential provide the basis for judging whether or not suppression measures are needed. NC (753).

230. Crown closure measured on aerial photos can be used to delimit timber stands likely to succumb to bark beetle attack. A crown closure-crown diameter comparator has been used on aerial photos to relate the images to stand density conditions on the ground. The method directs the forest manager to those stands needing thinning first. PSW (749).

231. Many improvements have been made in airborne scanning instruments and in data preprocessing and processing techniques. Despite spectral and radiant differences measurable on the ground, the accuracy of airborne scanners is still not adequate. Indications are that a single-aperture system may provide more accurate results for insect surveys. PSW (750).

232. The spread and growth of bark beetle infestations are dynamic processes operating within a forest ecosystem. These changes can be characterized quantitatively by annually counting the number of dead trees on medium scale color aerial photographs followed up with some ground checking. An example is described in detail. PSW (746).

233. Automated methods of pattern recognition to identify land uses were used on microdensitometer readings of infrared film for each of three high-altitude aircraft missions and the Apollo 9 photographic mission. The results from Apollo 9 photography were as good as those from the high-altitude aircraft photography. PSW (747).

234. Multiseasonal infrared color photographs taken from high altitude and from space were scanned using an automatic recording microdensitometer. Film densities were related to ground conditions to develop signatures for thirteen forest and nonforest land-use classes. Further research is needed to isolate and make adjustments for undesirable variation. PSW (745).

235. Photointerpretation was tested for thirteen forest and nonforest land classes on high-altitude infrared color photographs. Comparisons made with the results of two independent studies indicate that microscale infrared color photography can be useful for forest area estimates and stratifying forest area in forest inventories. PSW (742).

236. Sensitometry is important in the automatic interpretation of aerial film. Several hypothetical examples are given to illustrate errors caused by using uncalibrated film microdensities in the analysis of infrared color films. PSW (744).

237. The RS-2 field spectrometer is lightweight and self-contained. It is designed to obtain simultaneous data in four light bands which are identical to those of the Earth Resources Technology Satellite multispectral scanner. This instrument has been used to show the relationship between target radiance measured on the ground and the target radiance measured 10,000 feet above the ground. PSW (751).

8. FOREST PEST MANAGEMENT

238. The natural factors that control changes in gypsy moth numbers are varied and interact with one another in complex but somewhat predictable ways. In the past, single approaches (e.g., parasites, insecticides) have been used in attempts to control the insect but with little success. The use of insecticides has reduced pest numbers for limited periods but has resulted in damaging effects on other components of the environment. An effective pest population management system must integrate use of the various natural control organisms with artificial control methods to achieve optimal control of gypsy moth populations with minimal adverse effects on the environment. Approaches to this objective are described. NE (755).

239. Research on methods of controlling the gypsy moth has centered at times on a wide variety of approaches. New insecticides and methods of application have been developed; exotic parasites and predators have been imported, mass-reared, and released; male annihilation techniques have been investigated; attractants have been identified, synthesized, and field tested, and environmental manipulation has been attempted. It is now evident that we must develop systems of pest management based on manipulation of the real-life processes that do in fact regulate gypsy moth numbers. Research and development efforts will involve the development of effective methods of measuring and assessing population changes and integrating this knowledge with proven manipulative techniques to manage gypsy moth populations. NE (754).

240. Intensive forest management practices are changing the role of known forest insect pests and creating new problems involving other insects previously considered innocuous. In the Douglas-fir and western hemlock stands of the West, damage by tree-killing insects in old-growth stands is gradually shifting to insect problems affecting stand establishment and management of second-growth stands. This will pose a challenge to pest management specialists and forest managers in the near future. PNW (756).

241. Forests provide a unique opportunity to develop truly sound and effective strategies to manage the insect pests that adversely affect productivity, value, and usefulness. Different economic and sociological values placed on forests pose an unusual challenge in determining what are the really critical pests and how, when, and where to take action against them. Both ecological and economic thresholds must be established for each pest, or pest complex, and these are not static in time or place. WO (757).

9. ROOT DISEASES

a. Annosus root rot

242. An up-to date bibliography of world literature on annosus root rot has been compiled. The bibliography supplements an earlier one

covering work up to 1960 and covers the period 1960-1970 adding nearly 600 new titles. SE (413).

243. A common wood inhabiting fungus, Peniophora gigantea, effectively controls annosus root rot in southern pines. Techniques have been developed for commercial production of inoculum and operational application during thinning operations. (426, 427).

244. The spread of annosus root rot in thinned shortleaf pine plantations in Missouri was studied over an 8-year period on plots established in 1963. Mortality from the fungus has declined since 1965, but the decline has been more rapid since 1968. NE (409).

b. Poria root rot

245. Biological control of Poria root rot and improvement of genetic resistance can be advanced by understanding the biochemical nature of host resistance and susceptibility. Natural chemicals associated with resistance or susceptibility were identified in the roots of red alder and Douglas-fir. These and other compounds probably account for relative resistance of red alder to the disease. PNW (415).

246. Poria root rot may be controlled by antagonistic soil micro-organisms. Urea and wood shavings, incorporated in potted forest soil, greatly increased numbers of these soil fungi. One species of Trichoderma which was increased by addition of urea under laboratory conditions was highly antagonistic to the Poria root rot pathogen. PNW (422).

247. Evaluation of the impacts of forest diseases may best be accomplished with the aid of aerial surveillance. Remote sensing techniques have been developed which permit identification of Poria root rot centers in the Douglas-fir-western hemlock forests. PSW (435, 436).

c. Nematodes

248. Lance nematodes parasitize and damage roots of the Ocala race of sand pine in west Florida sandhills. The Choctawhatchee race of sand pine is now being planted instead of the Ocala race because of its apparent resistance to Clitocybe root rot. Greenhouse studies on seedlings indicate neither race of sand pine is resistant to lance nematodes. SE (430).

249. The parasitism and pathogenicity of several species of nematodes were tested on red maple, sweetgum, yellow-poplar, American sycamore, and swamp cottonwood. Some trees suffered severe root damage. These studies suggest that some hardwood plantings may fail, particularly if planted on agricultural lands infested with nematodes parasitic to agronomic crops. SE (410, 428, 429).

250. Nematodes feed and reproduce on several species of mycorrhizal and plant pathogenic fungi. The nematodes had no effect on viability of a number of the fungi, but some failed to revive when transferred to a

fresh, artificial medium. Fungus -feeding nematodes have the potential to reduce or inhibit pathogenic or mycorrhizal fungi under natural conditions. RM (425).

d. Mycorrhizae

251. Techniques are being developed and improved to classify and culture mycorrhizal fungi. The role of mycorrhizae as biological deterrents to root disease is now better understood. Studies have provided needed information in understanding the role of these important organisms in forest ecosystems. Artificial inoculation of seedlings with selected mycorrhizal fungi will reduce root disease losses and possibly permit regeneration of severely disturbed sites such as strip mine spoils. PNW (432, 439), FPL (423), SE (416).

252. Host genotype significantly influences mycorrhizal development. Some progenies of slash pine showed marked differential susceptibility to infection by mycorrhizal fungi. These findings may explain growth differences between progenies of pine planted on different sites where different mycorrhizal fungi are present. SE (420).

253. The occurrence or function of endomycorrhizae on trees is poorly known. Techniques were developed to form certain endomycorrhizae on the roots of citrus species. These studies will provide needed information to explore endomycorrhizal development on other tree species, particularly hardwoods, so their function and importance can be determined. SE (421).

254. A system for classifying mycorrhizae of Douglas-fir and identifying their fungal component has been developed. A tuberculate mycorrhizae was found which was antagonistic to pathogens causing annosus, Poria, Pythium, and Phytophthora root rots. Using the new system, ecological requirements of this and other mycorrhizal fungi may be readily determined and their potential in biological control of root disease evaluated. PNW (440).

255. A new root protecting function of mycorrhizal fungi has been discovered. An ectomycorrhizal fungus deactivates soil toxins that severely aborted root growth and stunted Douglas-fir seedlings without mycorrhizae. Mycorrhizal fungi probably aid tree growth in nature by protecting feeder roots from soil toxins. PNW (438).

(For an additional item relating to II B 9d see paragraph 250.)

e. Miscellaneous root diseases

256. Environmental stress and defoliation of sugar maple causes a change in the chemical constituents of the roots. Extracts from the roots of defoliated trees significantly increased growth of the Armillaria rot root pathogen. The studies suggest that environmental stress and defoliation of trees by insects may predispose them to Armillaria root rot. NE (424, 433, 434).

257. Mortality from Armillaria root rot in ponderosa pine plantations in New Mexico was inversely related to tree height. These findings suggest that this root rot may significantly affect early survival of ponderosa pine in New Mexico plantations. RM (437).

258. A serious, new root and butt rot of deodar cedar caused by Peniophora has been discovered in India. The previously unknown disease causes heavy losses in deodar plantations. WO (408).

259. A new species of Pythium was isolated and described from dead feeder roots of declining loblolly pine in the Gulf Coastal Plain of Louisiana. Other species of this fungus are serious root pathogens, but the relation of this species to declining pine in Louisiana is not fully understood. SE (411).

260. Several species of Phycomycetous fungi including a number of serious feeder root pathogens, were isolated from soil collected in old growth forest sites in Kentucky, Tennessee, and North Carolina. The studies suggest some species are indigenous and not widespread or did not survive conversion from forested to agricultural land. Other species are found commonly in both areas suggesting their ability to adapt to agricultural habitats. SE (412).

261. Phytophthora root rot causes significant losses in Fraser fir Christmas tree plantings in western North Carolina. This species is highly susceptible to Phytophthora root rot and should be replaced by white or Scotch pine where infested soil occurs. Fraser fir should not be planted in poorly drained or former shortleaf or loblolly pine sites. SE (414).

262. The littleleaf disease caused by Phytophthora root rot has prevented successful regeneration of shortleaf pine on certain sites in the southeastern United States. Growth and condition of geographic sources of shortleaf pine were evaluated after 16 years on three littleleaf disease sites in the Piedmont region. Results indicate shortleaf pine can be selected for adaptability to disease sites. SE (431).

10. STEM CANKERS

a. White pine blister rust

263. An international test program proposed by the IUFRO Working Party for Resistance of White Pines to Blister Rust includes reevaluation of naturally resistant white pines from near the original white pine blister rust pathogen gene center followed by sophisticated testing of North American white pines developed for resistance. Key test centers are proposed in Siberia, south-central Asia, the North Sea-Baltic Sea countries, and eastern and western North America. INT (442).

264. Recent studies show the white pine blister rust fungus grows normally in some western white pine needles until it reaches the short shoot. At this point, a resistance mechanism is triggered causing the host cell and fungus to die, thus preventing normal canker development. Such natural resistance mechanisms may be useful in breeding trees resistant to white pine blister rust. INT (453).

265. Western white pines from crosses of parents selected for resistance to white pine blister rust were examined for infection after 11 to 15 years in two areas. Progenies with general combining ability for resistance transmission were 20% infected compared to 58% infection in controls and 71% in natural reproduction. Although resistance to white pine blister rust is not complete, there is sufficient resistance to start planting of first-generation nursery stock. INT (463).

266. Great progress has been made in determining the nutritional requirements and growth regulating compounds of the white pine blister rust pathogen by studying host and nonhost tissue cultures inoculated with the pathogen. Development of such techniques clarifies the host-parasite relationships and provides the basis to develop effective chemical controls and understand mechanisms of resistance necessary to manage this destructive pathogen. (INT (447, 448, 449, 450, 458).

267. Low temperatures reduce the potential for production of pine-infecting spores of the white pine blister rust. Reductions in inoculum potential is almost in direct proportion to decreases in temperature from 60° to freezing. This finding suggests that low temperatures and a minimum of late-summer, moist periods reduce the hazard of rust infection to high-elevation white pine forests in the central Rocky Mountains. INT (456).

b. Fusiform rust

268. Alternate hosts for fusiform rust and eastern gall rust are similar. On the pine host, they cannot be distinguished morphologically. A new technique permits distinction between aeciospore collections of the two rust pathogens and provides invaluable identifications of inoculum used in screening pine seedlings for rust resistance. SE (445).

269. A technique was developed to patch graft fusiform rust and eastern gall rust infected tissue onto healthy seedlings. This study showed that the pathogen does not determine the shape of the gall, but that host response to the pathogen may be the governing factor. SE (459).

270. Different levels of fusiform rust resistance have been found in open-pollinated progeny of loblolly pine. Resistant progeny consistently had less infection than ordinary open-pollinated progeny not selected for resistance. This discovery is the first step in identifying resistance in loblolly pine. Screening seedlings for rust resistance is now feasible. SE (461).

271. Meteorologists can accurately predict weather that favors fusiform rust infection of southern pine seedlings in nurseries. Infection hazard forecasting for nurserymen will permit them to reinforce their regular spraying schedule with special applications. SO (444).

c. Other tree rusts

272. Loblolly and shortleaf pines are very susceptible to comandra rust in eastern Tennessee; Virginia and pitch pines, however, are less susceptible. Results of one study suggest that where heavy losses are sustained in planted susceptible species, alternative resistant species should be considered in replanting. SE (460).

d. Other cankers

273. The growth rate of some canker-producing fungi is increased by fluctuating temperatures. Actual growth rates of such organisms cannot be accurately predicted if constant temperatures prevail in the experiments. NE (454).

274. Ceratocystis and Diplodia canker were found in American sycamore plantings in the southeastern United States. The pathogens are extremely virulent in young sycamore plantings. Since the organisms normally enter through tree wounds, precautions are necessary to avoid losses from these pathogens in managing plantations. SE (462).

275. Natural regeneration of yellow birch in Wisconsin and Michigan is hindered by cankering, stem dieback, leafhopper oviposition wounds, and animal browsing. A number of canker-producing organisms have been associated with the problem, but further studies are required to determine their role. Serious suppression of yellow birch regeneration will occur if the problem is not checked. NC (455).

276. Ceratocystis canker is widespread throughout the western United States on aspen, frequently causing extensive stem damage which must be culled. Recent studies have positively identified the pathogen and described the disease process. Nitidulid beetles have been identified as vectors of the pathogen. This information provides a basic understanding of the disease process and may give useful leads for control. RM (451, 452).

277. Septoria canker has been found on eastern cottonwood seedlings in Mississippi nurseries. Presence of the disease poses a problem for nurserymen propagating cuttings of cottonwood for clonal nurseries or commercial plantations. SO (446).

11. DWARF MISTLETOES

278. A taxonomic revision of dwarf mistletoes of the world has been prepared in which 32 taxa are recognized. Host relationships, evolution,

distribution, criteria for classification, and collecting techniques are discussed in the 234-page book. The distribution maps, keys, and color and black and white illustrations make it a valuable tool for students, scientists, and practicing foresters. RM (466).

279. Cooperative studies between the Forest Service and universities, and other Federal agencies have produced important findings on the physiology, cytology, evolution, and insect associations of dwarf mistletoes. RM (469, 471, 474).

280. A computer program has been developed to compute yield tables for dwarf mistletoe-infected lodgepole pine in Colorado and Wyoming. This procedure provides foresters with the first practical tool for making decisions in managing timber where this destructive parasite is present. RM (470).

281. An illustrated glossary containing 260 dwarf mistletoe terms has been prepared. It will be a useful tool for researchers and dwarf mistletoe control personnel. RM (465).

282. Research sponsored in the western Himalayas has shown that dwarf mistletoes cause a serious economic loss in blue pine. The parasite, its distribution, and control are described. WO (464).

283. Studies of dwarf mistletoe seed dispersal in Jeffrey pine were conducted in California. Seed production and distance of spread were determined. Storms may aid in dispersal and considerable variation may occur in numbers of seed produced from year to year. PSW (472).

284. Control studies in ponderosa pine stands show dwarf mistletoe was not eliminated after 10 years, even with yearly sanitations, because of latent infections in the remaining tree crown. Results suggest silvicultural control of dwarf mistletoes will be most successful where infection is very low. PNW (473).

285. PL 480-sponsored scientists in India are investigating enzymes and their inhibitors in mistletoes. Certain types of enzymes may play a role in the process of parasitism and absorption of carbohydrates from the host. This information may lead to chemical or genetic control of these parasites. WO (467, 468).

12. VASCULAR WILTS

286. Techniques have been developed to solubilize the fungicide benomyl for injection into elm, oak, and maple. This breakthrough gives new hope that destructive vascular wilts such as Dutch elm disease, oak wilt, and *Verticillium* wilt can be controlled. NE (477, 479, 480).

287. Studies have been conducted on the transpiration, vascular water flow, and pathogen isolation in oak wilt-infected trees. Results of these studies have provided a basic understanding of the movement of fluids in vascular diseased trees. NE (475, 476).

288. Attempts to control fungus mat formation and oak bark beetle vectors in oak wilt-infected trees in the Northeast by treating with the herbicides, 2, 4-D, and cacodylic acid or tree felling were not successful. Different approaches are necessary to control the long-range spread of oak wilt. NE (481, 482).

289. Programs to control oak wilt in Pennsylvania and West Virginia have produced inconsistent results. These findings will provide a basis for decisions to continue, alter, or terminate oak wilt control programs in both States. NE (478).

13. FOLIAGE DISEASES

290. Spore trapping studies show that spores of the brown spot needle blight fungus are produced throughout the year in the South. Greatest quantities occur from April through August and coincide with new flushes of needle growth. Additional research is needed to clarify the role of temperature-moisture interactions in the infection process. SO (485).

291. A widespread needle blight of slash and loblolly pine in 1970-71 in six Southern States has been attributed to three fungal pathogens. Although slight growth reduction has probably resulted from infection by these pathogens, little or no mortality has resulted. Direct control with fungicides does not appear to be warranted. SO (484).

292. In 1970. Dothistroma needle blight in Minnesota rendered many Austrian pine Christmas trees unsalable. Severe defoliation of trees up to 8 years old resulted in mortality. The disease can be controlled by chemicals but the economic feasibility is questionable. Trees genetically resistant to the needle blight, may offer the best solution. NC (486).

293. Diplodia shoot blight has recently caused serious damage to Austrian, Scots, and ponderosa pine in the central Great Plains of the United States. Basic information on spore dispersal, germination, and the infection process has been determined. Study results indicate protection by fungicides is required to avoid serious losses. RM (483).

294. An outbreak of the Lophodermium needle cast fungus is causing serious defoliation of Scotch pine Christmas tree plantings in 11 States and British Columbia. Studies indicate the fungicide maneb will control the disease. NC (488).

14. AIR POLLUTION DAMAGE

295. Studies show significant variation among hybrid poplars in tolerance to SO₂ fumigation. Where possible, clones tolerant to short-term exposures of high levels of SO₂ should be selected for planting where air pollution may be a problem. NE (490).

296. The photosynthetic response of red maple seedlings fumigated with SO₂ is being studied. Information from these studies is essential in calibrating host response to pollutants, understanding the mechanism of pollution damage, and predicting the tree's potential for removing certain pollutants from the air. NE (494).

297. Study of ponderosa pine needle tissue fumigated with ozone showed that the destruction of chloroplasts was the first damage. Associated changes in the needle chemistry were decreases in carbohydrates and disruption of proteins and nucleic acids. PSW (491).

298. The incidence of oxidant air pollution damage was investigated in 8 air basins in California. Ponderosa, Jeffrey, Coulter, and Monterey pines and bigcone Douglas-fir were most severely damaged. The study indicates there is potential for more extensive damage to mixed conifer forests of the Sierras. PSW (493).

15. DETERIORATION OF WOOD

299. Engelmann spruce may now be effectively managed to avoid decay. Studies suggest that decay in young stands in the future will be negligible if wounding is minimized during silvicultural operations. PNW (495).

300. Single basidiospores isolated from some wood-rotting fungi can form fruiting bodies and viable spores in culture. Studies were conducted to examine this phenomenon cytologically and determine its significance in the decay process. SO (496).

301. The production and role of extracellular hydrogen peroxide is being studied in certain wood-rotting fungi. Important findings suggest this chemical may be involved in plant pathogenesis and degradation of plant constituents by wood-destroying fungi. SE (509, 510).

302. The rapid invasion of southern pine logs by stain and decay fungi after cutting has caused serious problems in handling, storage, and utilization. Recent studies suggest that while there may be some loss in non-cellulose components of the wood, storage under continuous water spray is an effective way of preventing these problems. SO (500, 501, 512).

303. For the first time, an annotated bibliography is available on the prevention and control of decay in wooden structures, including boats. This compilation will be a valuable aid to wood technologists and pest management specialists. SO (497).

304. Techniques have now been developed which promise extended serviceability of exterior woodwork. Long-term studies in diverse climates covering periods up to 19 years indicate dip preservative treatment of wood for exterior use will materially extend its usable life. PNW (511), SO (518).

305. A new obligate anaerobic bacterium has been isolated from stained wood tissue in living hardwood trees. Further research is required to determine the significance and function of this organism in the stain and decay process. NE (516, 517).

306. Wounds in trees initiated the sequence of events that lead to discoloration and decay. Studies now show that certain chemicals may retard the development of discoloration in wounds on red maple. NE (506, 507).

307. Studies are being conducted on the succession of microorganisms and patterns of discoloration and decay after wounding in red and white oaks. Results of these studies will provide a basic understanding of these processes and, perhaps, lead to means of preventing losses. NE (515).

308. Standard methods for testing natural resistance of wood to decay have been improved. A new technique provides a more accurate evaluation of wood decay and has led to the adoption of a new American Society for Testing and Materials (ASTM) standard for determining the natural durability of wood. FPL (504).

309. Little information is available on service records of laminated wood used in ship construction. Inspection of wood minesweepers after approximately 15 years' service revealed negligible decay. Results suggest wood components of similarly constructed ships will remain serviceable for several years. FPL (505).

310. Different methods of determining loss of wood substance caused by fungal attack in pulpwood chips stored outdoors have been evaluated. Results have shown the specific gravity method is an accurate and reliable technique for determining fungal degradation in stored pulpwood chips. FPL (502, 503).

16. FOREST FUNGI

311. Forests are an association of countless numbers of organisms. As we strive to protect and wisely manage complex forest ecosystems, serious voids in our knowledge of microorganism occurrence and function must be filled. Recent studies by Forest Service scientists throughout the United States have contributed to our understanding of forest fungi. Monographs have been prepared on several genera of fungi. The occurrence and ecological functions of a number of new species of fungi have been recorded. Important, new mycorrhizal fungi have been identified and their probable functions described. Information derived from these studies will

provide possible new leads to such things as biodegradation of forest residues, nutrient recycling, regeneration of severely disrupted sites, and biological control of forest pathogens. FPL (525, 527, 528, 529, 537), SE (522, 526), RM (521), PNW (524, 532, 533, 534, 535, 536).

312. Fungi representing 30 genera were isolated from fruit and seed of northern hardwood trees. Further research is required to determine their importance in seed storage and germination. NE (523).

313. PL 480-sponsored research in Pakistan has generated valuable information on new fungal records of white mulberry and Ganoderma root rot of sissoo. Effective control of these tree pathogens may now be accomplished. WO (519, 530).

314. PL 480-sponsored disease research in India has revealed a number of new diseases of exotic conifers and hardwoods. Early study and identification of these problems, some with international significance, will lead to effective control before serious epiphytotics occur. WO (520, 531).

17. MISCELLANEOUS STUDIES

315. The pathology of forest and shade trees of the United States has been compiled in one book. This unique 658-page publication is organized by the host attacked instead of by causes of the disease. A short description of silvical characteristics of each host species is followed by sections on seedling, foliage, stem and root diseases, trunk rots, mycorrhizal relations, and miscellaneous pathology. This monumental reference book will be an invaluable aid to students, researchers, and pest management personnel. WO (543).

316. Sirococcus tip blight was reported for the first time in California tree nurseries. The disease on Jeffrey pine can be effectively controlled by chemical fungicides. PSW (562).

317. Seedling mortality after outplanting is a constant problem when regenerating extensive areas. Scientists are investigating root pruning as a way to improve root systems of Douglas-fir and reduce seedling losses in plantations. PNW (564).

318. Diseased trees presently pose hazards in recreation areas because of breakage or windthrow. An analysis of factors involved in recreation site hazard has been completed. A guide now is available for rating hazard and making control decisions in recreational areas. PSW (552).

319. Climate profoundly influences the growth of forest trees. In recent studies, pole blight of western white pine has been associated with a 24-year period of severe moisture stress. Unless an unfavorable climatic shift reoccurs, pole blight is not expected to be a problem again for several centuries. INT (550).

320. Mycoplasma-like bodies have been associated with the phloem necrosis disease of American elm which is epidemic in some parts of the United States. If mycoplasms are the cause of phloem necrosis, originally attributed to a virus, the possibility exists that antibiotic treatments will control the disease. NE (572).

321. Recent studies have shown that crown gall of hybrid poplars may be controlled by applying antibiotic solutions to stem tumors NE (545).

322. Dieback and decline diseases are often initiated by environmental stresses including drought and temperature extremes. Effects of stresses are not well understood, but studies show that the most drought-resistant trees were also the most heat resistant. In addition, an unusual structure has been found in conifer needles which may explain drought resistance in some tree species. NE (554).

323. A number of technological advancements have been made in germ-free plant research. Methods for seed sterilization, certification of seedlings as germ-free, and maintaining tree seedlings in a sterile environment have been developed. No ill effects were observed when a number of green plants were grown in the presence of lunar materials returned by Apollo 12, 14, and 15 missions. These findings are further evidence that lunar materials pose no hazard to living systems on earth. SO (538, 547, 549, 565, 566, 567, 568, 569, 570, 571).

324. Mistblower applications of the fungicide Ferbam, successfully protected artificially inoculated slash pine strobili from infection by southern cone rust. This technique may be useful in protecting slash pine seed orchards from heavy losses caused by cone rust. SE (540).

C. Accelerating Forest Resource Surveys

1. FOREST INVENTORY

Sharp increases in timber demands for residential constructive have again caused concern about the adequacy of the Nation's timber supply. In a continuing effort to provide current information for timber supply analysis, field surveys were conducted in Alabama, Alaska, California, Connecticut, Georgia, Hawaii, Missouri, New Jersey, New Mexico, Oregon, South Dakota, and Tennessee. Reports appraising the forest resource situation were issued for eight States or portion of States. Approximately 45 million acres of commercial forest land were re-inventoried during the past year. At this rate the resurvey cycle averages 11 years.

325. Florida's forest area declined 5 percent between 1959 and 1970 because of diversions to agriculture, urban and other users. Meanwhile, timber volume increased from 9.1 to 10.9 billion cubic feet, or 20 percent, despite the reduced area base. About 79 percent of this increase was in softwoods.

In 1969, net growth exceeded timber removals by 184 million cubic feet, or 53 percent. The higher inventory is manifested by a reduction of nonstocked forest land from 6.9 to 2.6 million acres. Area planted averaged over 200,000 acres annually. About 2.0 million acres, or 12 percent of the commercial forest lands, have been artificially regenerated between 1959 and 1970. SE (99, 100).

326. The trend toward less forest land was also detected in the Delta Region of Arkansas, Southeast Georgia, Northern Michigan, East Tennessee, and Wisconsin by recent surveys. NC (92), SE (87), SO (94, 102, 103).

327. In Maine where forest industries own 49 percent of the commercial forest land, forest area increased 3 percent between 1959 and 1971. A general trend in the East is illustrated in Maine by a 23 percent gain in growing stock volume. Annual growth for 1970 was 711 million cubic feet, well above removals of 409 million cubic feet, although more white pine, northern white cedar, yellow birch, and sugar maple sawtimber is being harvested than grown. The largest increases in volume occurred in spruce and balsam fir, both major pulp species. NE (93).

328. The southern forest resource is rapidly changing. Because of the 10-year interval between statewide surveys, available forest resource information is often neither current nor detailed enough for local needs. In a test to expand the utility of forest survey statistics, a computerized system for annual updating of basic data was developed. The updating system, incorporating timber growth and removals estimates, was used to produce current resource and production statistics for the 370 counties in 6 southern states. SO (88).

2. TIMBER UTILIZATION AND PRODUCTION

329. Efficiency of timber utilization was investigated in the Northeast and Pacific Coast regions of the U.S. Nearly one-fifth of the timber harvested in the Northeast was lost in the process of converting to products. Eighty-five percent of this was left as logging residue in the woods. Much of the plant residues were salvaged, primarily for pulpchips.

In the Pacific Coast region, logging residues have trended downward from 23 percent of the harvest in 1952, to 15 percent today. Manufacturing residues have increased in recent years, but a higher proportion is now being remanufactured into useful byproducts. PNW (115, 116), NE (113).

330. A study of pulpwood production and utilization in the South Central States shows that average hauling distance has remained substantially the same since 1960. Pulpwood production in the South continued upward in 1970 reaching a peak of 42 million cords. A significant departure from past trends are recent gains in the use of oaks and other hard hardwoods for pulping. SO (104, 106).

331. Pulpwood procurement patterns analyzed in the Northeast reveal considerable change in recent years as old, inefficient mills close or convert to new pulping processes, and high-production mills open. Pulpwood production rose 11 percent over the previous year. NE (114).

332. In the North Central States, pulpwood production also reached a new high, spurred by marked advances in both pine and birch. The use of paper birch signifies an important development in pulping technology that will add to the utility of this widely available species. NC (107).

333. Pulpwood prices were reported for both the Southeast and South Central regions. Although modest gains were observed in 1970, relative prices actually declined. Differences still prevail between the two regions with eastern prices averaging more than \$1 per cord more for pine. Hardwood prices are only slightly higher in the East. SE (120), SO (105).

334. Sawlog production in Kansas and Iowa was highlighted by two reports from the North Central Station. Important species common to both States are cottonwood and elm. In these States, very little of the wood residue from sawmilling is used. NC (111, 112).

335. Veneer manufacture was analyzed in the North Central, Southeast, and South Central regions. Throughout the East, hardwood veneer production is gradually declining. In the last decade, however, large scale expansion in the manufacture of southern pine plywood has drastically altered the industry. In the South Central region where plywood plants are concentrated, a fivefold increase in veneer output occurred between 1963 and 1970. NC (117), SO (122), SE (126).

3. SURVEY TECHNIQUES

336. Site-index comparisons were developed for quaking aspen, paper birch, basswood, red oak, black ash, jack pine, red pine, white pine, white spruce, black spruce, balsam fir, and tamarack in northern Minnesota. Knowledge of site index relationships among species is necessary for rating site potentials in major forestry treatments such as type conversion. NC (127).

337. Accuracy of standing-tree volume estimates using the McClure Mirror Caliper, an optical dendrometer, was tested by comparing standing tree volume estimates with measurements after felling. The results demonstrate that the Mirror Caliper estimates are within 2 percent of the felled tree volume check. SE (128).

338. A case study using two Arkansas Forest Survey regions incorporated a functional forest resource appraisal. This approach combines the timber inventory, with sources of relevant information about other functions such as recreation, to overcome deficiencies in appraisals that deal solely with timber production. SO (131).

(For additional items relating to II C 1 see paragraphs under III A 7; to II C 3, see under II C 1.)

D. Economics of Forest Management

1. METHODS OF FINANCIAL EVALUATION AND PLANNING

339. Capital budgeting techniques have been developed for ranking investment alternatives for which the rate of return varies with the amount invested. The technique proposed develops a new type of capital demand schedule that aggregates the marginal rate-of-return curves of individual projects. This leads to a greater investment in projects promising the highest rate of return, and results in a more efficient allocation of capital. NC (4).

340. A new computer program for discounting benefit and cost flows over time interpolates values for years for which no data are supplied and permits combining flows of differing lengths. Outputs of the program include discounted present values of individual costs or benefits, and summed net present value for an entire project. RM (2).

341. Computer-prepared tables present 10 selected compound-discount interest rate multipliers commonly used in financial analyses of forestry investments. The first set of tables gives multipliers for each year from 1 to 40 years; the second set gives multipliers at 5-year intervals from 5 to 160 years. Multipliers are given for 24 selected interest rates from 0.5 to 30 percent. NC (6).

342. In a comparison test with two traditional techniques of forest control and regulation, a new computerized planning system called Timber-RAM allows a more realistic definition of timber resources and can analyze a wider spectrum of forest management practices. The traditional methods using linear programming are simpler to apply and less expensive. Inventory data from a National Forest in California served to illustrate how each technique is used. PNW (3).

2. TIMBER GROWING ECONOMICS

343. An operational version of Timber-RAM (Resource Allocation Method) provides a long-range planning tool for commercial timber lands under multiple-use management using linear programming techniques. Timber-RAM can produce cutting and reforestation schedules and related harvest and economic reports for an area the size of a National Forest over several rotations. Each schedule optimizes an index of performance, subject to periodic constraints on revenues, costs, and harvest levels. Constraints can also be used to regulate forest stands and to even out the flow of timber during conversion. PSW (17).

344. Guides for investors considering removal of low-value stands to establish pine plantations indicate financial returns for various levels of expenditures, and for separate species, site indexes, different levels of costs and prices. Both immediate conversion and delayed conversion,

with and without timber stand improvement are considered. Opportunities for forest type conversion exist on 50 million acres, and occur in every ownership class. SO (8).

345. Rates of value increase developed for 10 species common to the oak-hickory type are useful for evaluating individual trees, and for evaluating future diameter growth, increase in merchantable height, and improvement in tree quality in stands. The method is applied to all forest-management techniques. The rate of value increase is the measure that, combined with basal-area requirements of silviculturists, provides a more adequate base from which to determine what to cut. NE (9).

346. Simulation techniques were successful in determining the cost, yield, and price conditions which would make silage-sycamore profitable and in indicating areas where additional research and refinement are necessary. Costs of establishing and maintaining silage-sycamore plantations were found to be extremely high relative to other forest species, eliminating silage-sycamore as a profitable land use for independent growers who wish to market the crop as stumps. Industrial landowners may compensate for these costs if they purchase specialized equipment and plant large acreages. SO (10).

347. A survey of forest industry firms provides current estimates of the costs of practicing forestry in the South and depicts cost changes and trends for the period 1952-67. Eleven major practices are analyzed in detail: controlled burning, seeded preparation by bulldozing or disk ing, planting open land by hand and by machine, planting cutover land by hand and by machine, cutting to release young growth, poisoning undesirable trees, girdling undesirable trees, cruising, and marking trees for harvest. Costs increases varied from 200 to 700 percent over the 15 years, exceeding the inflation in the general economy and in prices received for forest products. SO (15).

348. For purposes of the Federal income tax there are two types of logging roads--permanent and temporary. The tax status of permanent road costs is relatively clear. There is substantial legal confusion as to whether temporary roads can be treated as business expenses, or should be capitalized as a cost of the timber. The controversy has been described in detail, as well as other tax aspects of logging roads. SO (13).

3. MULTIPLE-USE ECONOMICS

349. The area of forest land now considered suitable and available for sustained timber management on six western National Forests is about one-fifth less than previously reported. The reduction in area estimates reflects more precise consideration of land productivity, land instability, isolation of small stringers and patches of forest land, and impacts of improved multiple-use planning. Revised classifications of forest land in terms of planned use contributed most to the reduction of areas classed as commercial forest land. Impacts on allowable cut will be less than the reduction in area. INT (18).

350. Timber and water response data from studies of watersheds at the Fennow Experimental Forest provide an approach for evaluating streamflow increases in terms of value of timber growth foregone. Light cutting slightly increased values of both timber growth and streamflow. Cutting three-fourths or more of the forest vegetation provided major increases in streamflow but no return from timber during the 10-year period of regrowth. Average annual water costs ranged from 0 to \$1.30 per thousand gallons. NE (19).

351. Concern for the environment has all but bypassed considerations of ground-water pollution. The opportunity cost of replacing ground water with alternative sources imparts a very high value to the resource. Though ground water is generally less vulnerable to pollution than surface water, this lower susceptibility is swamped by the consequences of ground-water contamination. The time required for a sizable aquifer to become contaminated is negligible compared with the time required for the system to flush itself of the pollutant. RM (16).

4. IMPACTS ON FOREST INDUSTRY AND REGIONAL ECONOMIES

352. Owners of large forest acreages sell forest products more frequently, undertake forest management more often, and are more interested in income producing potential of their forest tracts than owners of small tracts. A sample of nearly 400 owners in 3 different areas of Pennsylvania provided information to develop a sound basis for assessing the role of individual woodland owners as suppliers of forest products and services. Most of the owners said they have not obtained information about management and marketing of forest products during the past 5 years. Only a very small percentage of all the owners entered into formal government programs. NE (26).

353. Analysis of output-per-man-hour data for 1947-67 indicates that productivity rose for all major forest products industries at an average annual rate of 3.3 percent. Particularly remarkable was the substantial improvement in the lumber and wood products sector whose productivity increased annually by 3.2 percent, about the average for all manufacturing. Actual employment, however, dropped 14 percent. Another major increase was in the paper industry whose productivity increased at an annual rate of 3.4 percent. SO (24).

354. Forest industry in the South appears to be gaining progressively in its competitive position relative to the same industries in other regions or the nation as a whole. In the South, forest-based industries can be categorized as rapid-growth components of the region despite slow growth patterns nationally. The South is gaining markets for forest products due to shifting nonforest industries and populations, a relative gain in resource availability, and recent technological innovations in forest-product processes that have altered input that favor smaller trees. SO (25).

355. A regional location model has been shown to accurately predict the direction of regional shifts in plywood and lumber industries that have taken place in the last 5 years. Recent movements in regional stumpage prices, however, do not agree with those projected by the model, probably because the model assumes regional stumpage markets are equally competitive and all species are perfect substitutes in production and consumption. If these assumptions are more nearly true in the future, long-run relative increases in southern pine stumpage prices are likely. SO (23).

E. Improving Engineering Systems

356. Both balloon and skyline systems of harvesting have proven their effectiveness for harvesting timber in mountainous areas. Each system has its advantages and disadvantages. A new system combining the two is now under consideration. Preliminary considerations indicate the new system would approach the ideal by combining the best features of both while minimizing the disadvantages of each. If the results of planned operational tests are favorable, an economical method will be available for logging long spans in swampy forests and appropriate difficult-to-log mountainous terrain. PNW (780).

357. Today's widespread concern for the environment necessitates reorientation of the economic analyses and methods used to determine forest road locations and standards. Presently, we lack much of the data needed for total analysis and planning for truly optimum forest road systems. Certain information and means are available, however, that emphasize environmental quality protection. A procedure that might be considered to help decide on appropriate locations and standards, until better data are available, has been developed. INT (770).

358. The woods labor force, relied on heavily by the gum naval stores industry, is steadily diminishing. It may be necessary eventually to collect gum by a system requiring little or no labor. A cooperative study between the Forest Service and a private operator has resulted in a pilot operation employing commercial laborers and the first fully mechanized pine gum harvesting system in the United States. Results were encouraging, though production rates were low. No major obstacles to further development of the system were evident. SO (767).

359. An efficient and economical system for segregating bark and wood chips will greatly enhance possibilities for broader use of logging residues. A system involving air flotation to accomplish the separation is a unique possibility and information on the terminal velocity of the two materials, basic to design of the system, has now been developed. Preliminary research results show a significant difference between terminal velocities of aspen wood and bark chips, thus making air flotation a promising segregation method. NC (784).

360. Training programs for novice wheeled-skidder operators are usually unavailable at most Appalachia logging operations. Untrained operators are inefficient, sometimes a safety hazard, and can contribute

to ecological damage. Experimental test experience has disclosed many techniques necessary for efficient operation of that type of machine involving such areas as bunching logs, load selection, loaded and empty travel, blade use, preventive maintenance, and the like. The information presented can be used as a training tool to develop skilled logging machine operators capable of providing efficient, safe, and ecologically improved logging. NE (776).

361. The running skyline system, a logging system using two or more suspended moving lines, is being used by an increasing number of timber operators. A procedure using a desktop computer/plotter can be employed to plot terrain profiles, ascertain and plot the path of running skyline carriage, and determine running skyline load-carrying capability over a given ground profile, as shown by a recent study. Computer programs for implementing the procedure have also been developed. The information is useful to the logging system designer who is investigating application of running skyline systems in his harvesting plans. PNW (766).

362. Logging balloons, in a range of sizes, are operated in a variety of atmospheric conditions. Fundamental principles of aerostatics and thermodynamics can be used to compute influence of these conditions on gross static lift. A report on recent studies establishes parameters influencing static lift, shows how it can be computed, and provides nomographs for field computations based on pressure, temperature, and volume values. This provides the balloon logger with the information required to calculate changes in lifting potential as operations and environmental conditions change. PNW (765).

F. Improving Water Quality and Yield

1. IMPROVING WATER YIELDS

a. Vegetative manipulation

363. During the first 2 years following chemical treatment of trees and shrubs along well-defined stream channels of a 246-acre chaparral-covered watershed in Arizona, both duration and volume of streamflow increased. Streamflow, which was usually intermittent during summer and fall, became continuous and yielded increases of 32 and 54 percent for 1968 and 1969, respectively. RM (226).

364. Cutting along mid-contour lines on forested watersheds on the Fernow Experimental Forest established that quantity and timing of yield was little influenced by the site of cutting. When the upper half of one watershed and the lower half of an adjacent one were maintained barren for 3 years, annual flow increases on each held close to 6 inches. Flow increases rose to 10 inches annually after both watersheds were completely deforested and kept barren. NE (234).

365. Long-term average water yield of a watershed appears to be a good index to the magnitude of its expected peak flow, and on the basis of this criterion, tables were prepared showing expected peak flows that are applicable to watersheds in Idaho and Montana. The tables may be used to help solve problems on effects of clearcutting operations, channel stability, bank cutting, and stream level. INT (212).

366. Conversion of forest land to urban uses in the Northeast will likely produce increases in water yield, storm runoff, and sedimentation, with the latter resulting primarily from construction. However, under certain circumstances, partially urbanized watersheds may produce lower peak flows and require longer periods to discharge equal amounts of water than forested watersheds. Forested areas within larger cities may be useful for disposal and renovation of waste water, groundwater recharge, and soil stabilization. NE (231).

367. A study in the Northeast showed that snowmelt differences among forest covers result from variations in energy transfers by solar and longwave radiation, convection, and condensation-evaporation. Many of the complex energy exchanges taking place in a hardwood forest snowpack are presented along with models to describe the process. NE (220).

368. Logging and burning old-growth Douglas-fir forests on an experimental watershed in the Pacific Northwest increased annual water yields by 18 inches or more. Treatments generally resulted in year-long increases in streamflow as well as substantial increases in minimum streamflow during dry summers. If sedimentation is kept at a minimum, such increases in streamflow patterns will likely benefit aquatic habitat. PNW (237).

b. Soil and other influences

369. Contour trenching of about 15 percent of the upper slopes of a high mountain watershed in Utah did not result in significant changes in annual water yield or spring snowmelt runoff. However, peak spring flow and peak summer flow were reduced after trenching. Contour trenching has been widely used in rehabilitation programs on numerous similar watersheds in the western United States, and these results suggest that water yield will not be altered by this practice. INT (217).

370. Water repellency in certain soils may impede infiltration just beneath the litter or in the upper soil horizons, depending on nature of the vegetation, composition of the micro-organic community, physical properties of the soil and fire history of the area. In addition to affecting water yield, water repellency plays a role in soil formation, distribution and growth of vegetation, and erosional processes. INT (221, 232).

371. In a mixed hardwood forest in Ohio, macropores were found to consist of structural pores, open channels resulting from root decay, animal passageways, voids between roots and soil, and structural cracks. These macropores provide pathways or conduits for the rapid movement

of free water into and through the soil profile. In some instances, water movement was so rapid that only areas around the root channels were wetted. NE (210).

372. Ridge and coulee terrain in southwestern Wisconsin has little effect on point rainfall, but snowpack accumulation is affected by degree of slope and aspect. North slopes accumulate about 50 percent more snow, but aspect had little effect on soil water depletion. South slopes receive more insolation than north slopes although temperature differences are slight. Air drainage has a significant effect on night time air temperatures in coulee bottoms. NC (239).

373. Water collected on mountain logging roads when they are incised into the slope may be converted into rapid surface runoff, which may add to peak flow and threaten channel stability in mountain streams. Potential erosion through slumping of road banks and effects of such roads on the basin hydrograph should be considered in road planning. INT (215).

2. MANAGING WATERSHEDS

374. First-year results showed that snow fencing in southeastern Wyoming increased the water equivalent of the snowpack by about 70 percent on small watersheds, and demonstrate the potential for snow management in windswept areas. The snow fence system was designed to redistribute water on a drainage by concentrating snow in a relatively few large accumulations rather than many smaller drifts. RM (267).

375. Many of the forested municipal watersheds in the Northeast are located in or near densely populated areas and are receiving increased pressures for uses other than water yield. A recent survey showed that timber harvesting is allowed on 54 percent and some type of recreation on 59 percent of the watersheds. The survey indicated that management to increase water yield is successful on some watersheds, but is causing problems on others. NE (253).

376. Most upland runoff from overlying fields in the Driftless Area of Wisconsin was absorbed by forested slopes, with average lower station flow ranging from 56 to 94 percent of upland flow after large storms. The effectiveness of the forest zone in disposing of upland runoff appeared to be related to the ratio of forest to open-upland area. NC (265).

377. A method for revising streamflow forecasts based on snowpack depletion and precipitation in the Rocky Mountain West is presented utilizing a model which has enough flexibility to account for unusual hydrologic conditions. For one year, initial forecast errors were reduced by 10 percent. The method has promise for greater efficiency in reservoir operation. RM (258).

(For additional items relating to II F 2 see paragraphs 1, 364, and 369.)

3. WATERSHED REHABILITATION AND DAMAGE PREVENTION

378. Past land use, forest fires, road building, poor logging practices, and conversion of steep lands to grass have increased sediment production in the western United States by factors ranging from 1.24 to more than 4. Projected future use is expected to increase sediment production by a factor of 4, of which 80 percent would be associated with roads and 20 percent with logging. Quantitative measurements of soil characteristics, topography, land use conditions, and the meteorological impacts on these lands have provided a basis for predicting differences in expected sediment production from these sources. PNW (270).

379. In revegetating spoil banks in eastern Kentucky, growth of K-31 tall fescue was greatest where texture consisted of about equal parts of soil-sized material and particles 2 to 6.4 mm in diameter. This particle size distribution probably provides better physical soil properties, particularly aeration and moisture retention. Fescue grows best where soil particles are larger if spoils contain chemicals which limit plant growth. NE (282).

380. An intensive study of the effect of grazing on the hydrologic and biotic characteristics of small drainage basins on the Colorado Plateau has shown that ungrazed watersheds produced only 69 to 71 percent as much runoff as grazed ones. Sediment yield from ungrazed watersheds averaged about 66 percent of that on the grazed watersheds. Amount of bare soil and rock, ground-cover index, and amount of litter and moss changed significantly on grazed watersheds, but remained about the same on ungrazed ones. RM (278).

381. Dominant natural soil mass movement processes active on watersheds of the western United States are found to be encouraged or accelerated by destruction of natural mechanical support on slopes. Logging, road building, and fire play an important part in initiation and acceleration of these movements with road building providing the most damaging activity because of its effect on back slope cutting, slope loading, and drainage. Logging and fire may affect stability through destruction of natural support for the soils, removal of surface cover, and obstruction of drainage channels by debris. PNW (281).

(For additional items relating to II F 3 see paragraphs 1, 2, and 370.)

4. WATER QUALITY

382. Effects of logging and associated road construction on four northern California streams were not detrimental to anadromous fish production when adequate attention was given to stream protection and channel clearance. However, extensive use of bulldozers on steep slopes and in stream channels caused excessive sedimentation. Carrying capacities for juvenile salmonids were increased when high temperatures, low dissolved oxygen concentration, and adverse sedimentation did not accompany logging. PSW (286).

383. Cutting all trees and understory vegetation on small watersheds in the southern Appalachians resulted in increasing maximum summer stream temperatures by as much as 12 degrees F. above the normal 66 degrees F. which may exceed the optimum for trout habitat. Where streambank vegetation was uncut or had regrown, maximum summer temperatures remained unchanged. SE (291).

384. Timber harvest and slash burning on a watershed previously stocked with old-growth Douglas-fir resulted in nutrient losses 1.6 to 3.0 times greater than those on an undisturbed watershed. Nitrogen loss on the undisturbed area was about 0.16 pound per acre compared with 4.6 pounds per acre following the burning treatment. PNW (287).

385. Cleaning of gravel in three streams in southeast Alaska initially reduced bottom fauna populations in each stream, but within 1 year these populations apparently returned to pretreatment levels. The cleaning of gravel by removing excessive sediment is being done to improve spawning gravels for salmon production. PNW (290).

5. MEASURING ENVIRONMENTAL PARAMETERS

386. A portable, insulated evaporation pan was developed to give evaporation values that are highly correlated with those from standard U.S. Weather Bureau Class A pans, requires less water than conventional pans, and may serve as an all-wave radiometer for incident minus reflected light. This insulated pan may also be used at temperatures below 32 degrees F. INT (307).

387. A pump-manometer was designed to provide quick and accurate measurement of hydraulic conductivity in the field by means of either the auger-hole method or piezometer method. The device can be operated easily with a two-man crew, but with practice one man could perform the entire operation. The primary advantage of the manometer is that measurement of the rate of rise of water can begin as soon as the well is pumped dry without exchanging instruments. INT (302).

G. Bettering Silvicultural Systems

1. NATURAL REGENERATION

388. Knowledge of the seed crop characteristics of paper birch is essential for planning silvicultural measures to obtain successful natural regeneration of this species. A 3-year study in Maine revealed that about two-thirds of the total seed production is good seed, and that most of it is dispersed in October and November. Reasonably good seed crops occur about every other year, and adequate seed dispersal extends from about 30 feet into a forest opening in very poor seed years to more than 150 feet

in excellent seed years. This information will enable forest managers to schedule site preparation measures and to determine the appropriate width of clearcut strips. NE (968).

389. Knowledge of the chemical contents of fruits and seeds of trees can be very useful information in silviculture or wildlife habitat research. Analyses made on various seed collected in central Mississippi resulted in a list of values for crude fat, protein, total carbohydrates, phosphorus, calcium, and magnesium for 37 southern tree species. These analyses help appraise the place of the seed crops in the nutrient cycle as well as their food value for wildlife. SO (969).

390. Nurserymen have long been plagued by the very low percentage of full seed in yellow-poplar seedlots. A new method, developed in Mississippi, involving mechanical removal of wings and partitioning of the seeds into different specific gravity fractions to isolate full seeds, has resulted in upgrading of seed groups with an original soundness of 6 to 10 percent to 60 to 65 percent full seed. By using this method, nurserymen will be able to regulate bed density and thus seedling size for the first time. SO (970).

391. Accurate estimates of cone crops are needed to plan seedbed preparation and cone collection activities. In a 2-year longleaf pine study in south Alabama, it was found that binocular counts, made during early spring growth prior to needle development, multiplied by a factor of 1.5, give a conservative estimate of total conelets on a seed tree. SO (971).

392. Phytotoxic substances can drastically alter the development of forest and range vegetation. In coastal North Carolina salicylic acid leached by rain from the crowns of large cherrybark oaks reduced survival and growth of both natural vegetation and planted seedlings. Such losses seriously affect the regeneration and silvicultural management of mixed-hardwood forests. SE (972).

393. Southern pines are often difficult to regenerate through natural seedfall because of extreme fluctuations in seed crops. In loblolly and shortleaf pines on loessial soil in southern Arkansas, summer logging produced 63 percent stocking, burning prior to logging yielded 69 percent stocking, disking prior to logging increased stocking to 89 percent and bulldozing after logging gave 99 percent stocking. Land managers can regulate site treatment to include both desired stocking and cost factors. SO (973).

394. Erratic seed crops in forest stands mean that stored seed must be available to sustain tree planting programs. Studies in northwestern Pennsylvania yielded a successful method of storing black cherry seed for at least 3 years. Seed is dried either to 4 to 6 percent moisture content and stored in a freezer at 0° to 6° F., or to 4 to 15 percent moisture and stored in a refrigerator at 38° to 41° F. Use of this method to store black cherry seed collected in good seed years for planting in poor seed years assures continuity in planting programs. NE (974).

395. Standard guidelines for natural regeneration of southern bottomland hardwood stands in the Coastal Plains are not available but observations and research indicate that the preferred system of regeneration would keep the overstory dense until a combination of harvesting and cultural treatments provided openings and favorable seedbeds. Then, regeneration would come from advanced reproduction, sprouts from the roots and stumps of cut trees, and seeds either lying dormant in the litter or moving in from larger trees, within 200 feet of the opening. Foresters can use this information to improve regeneration on thousands of acres of southern hardwood forests. SO (975).

396. Natural regeneration of oak stands requires establishment of an understory before the final harvest cut. Studies in Missouri with 10 percent, 30 percent, and full sunlight showed that first-year red oak seedlings failed to respond to an NPK fertilizer unless they had 30 percent or more of full sunlight. The light requirements of older seedlings and of seedling sprouts must also be explored to make this information more useful in developing regeneration practices. NC (976).

397. Periodicity or cyclic rhythms characterize cone production of western white pine. The yearly number of strobili, followed on 4 trees during an 18-year period in northern Idaho, indicated that periodicity in production of strobili by individual trees followed major cycles of 4 years. Within this cycle, individual trees tend to be in phase. This information should help forest managers and research geneticists schedule activities that depend on timing of cone crops. INT (977).

398. When a mature stand of upland oak timber is clearcut a high percentage of the oak advance reproduction stems are broken off, cut or damaged in some way. Observations in Ohio indicate that most of these damaged stems sprout and become the fastest growing and most desirable form of oak reproduction. Stems between 0.5 and 1.0 inches in diameter produced sprouts that attained favorable competitive positions in the new stand. This information permits appraisal of the adequacy of advance oak regeneration before final harvest cuts are made. NC (978).

399. Alternatives to clearcutting are needed in many timber types. Although western larch grows best under nearly full sunlight in the northern Rockies, seedlings rarely become established more than 150 feet from the edge of timber without well-prepared seedbeds. The seed tree and shelterwood methods (4 and 13 mature trees per acre, respectively) are more likely to promote evenly distributed natural regeneration than is clearcutting. A rating system is now available to help land managers evaluate the effects of various silvicultural practices in western larch on costs of logging, regenerating, and culturing as well as the effects on wildlife forage, livestock forage, water, and esthetics. INT (979).

400. Little is known about the seed production of young-growth ponderosa pine along the westside Sierra Nevada. Ninety-year-old seed trees ranging from 3 to 9 per acre produced 5,000 to 35,000 seeds per acre in years of moderate to heavy cone crop, which occurred at intervals of 1 to

3 years. In this type of timber, a minimum of 4 seed trees per acre should be selected from among the trees that show evidence of past cone production. PSW (980).

401. Measurements made on even-aged hardwood stands in West Virginia indicated that 7 years after a seed tree harvest, stems of many species were abundant and well distributed. Large reproduction, destined to make up the next crop, consisted mostly of species that had either sprouted vigorously, exhibited fast early growth, developed from root suckers, or reproduced under the old stand. These results indicate the great diversity of species and abundance of reproduction that can be expected after even-aged harvest cuts in Appalachian hardwoods. NE (981).

402. Natural regeneration of shortleaf pine is unreliable because of greatly fluctuating seed crops. Removal of all trees within 30 feet of seed trees more than doubled cone production and increased the number of sound seeds per cone by 9 percent during a 3-year period in the Ouachita Mountains of Arkansas. Forest managers should consider this release technique for satisfactory natural regeneration of shortleaf pine. SO (982).

403. The forests of interior Alaska are a complex mosaic of stands which are, to a significant degree, related to the fire history of the area. A comprehensive summary of information concerning seed production, seedbed requirements, and vegetative reproduction has been prepared for the 5 major forest tree species--white spruce, black spruce, paper birch, quaking aspen, and balsam poplar. These data provide a quantitative basis for evaluating the reforestation potential of newly burned areas in interior Alaska. PNW (983).

404. A late May frost in interior Alaska killed or damaged developing conelets of white spruce, resulting in a reduction of more than 50 percent in cones and seeds in some stands. This is the first report of such damage during 12 years of cone and seed crop observations in this region; therefore, it probably has only minor influence on overall seed production. But because of the infrequent seed crops, frost damage could have an unfavorable impact on seed collection or other activities that depend on large amounts of seed from limited-area or special purpose stands. PNW (984).

2. SILVICULTURAL METHODS

405. Forest managers in the central Rocky Mountains are faced with the problem of changing established timber harvesting practices to meet the needs of all forest uses. Interim guidelines are now available to aid the manager in developing alternatives to clearcutting old-growth spruce-fir forests. Alternative partial cutting practices provide for maintenance of forest cover in recreation areas, travel influence zones, and scenic view areas; other patterns of cutting give options for increasing water

yield, improving wildlife habitat, or integrating timber production with other key uses. RM (985, 986).

406. A synthesis of past research shows that advance oak reproduction is the key to forming the new oak stand. However, the size and vigor of the advance stems is as important as the number. If oak stands approaching maturity do not have enough advance reproduction, harvest cutting must be delayed and overstory densities regulated to favor the establishment and development of new oaks in the understory. These results provide a basis for an understanding of oak ecology that is essential to the planning for uniform long-term flow of goods and services from oak forests. NC (987).

407. Western hemlock and Sitka spruce are generally harvested by clearcutting, but there are situations where some other method would be preferable for esthetic or other reasons. A study in southeastern Alaska showed that crop trees left in a 96-year-old stand after partial cutting were able to increase or maintain the same rate of diameter growth as before thinning, whereas diameter growth of unthinned trees declined. Partially cut plots became well stocked with conifer regeneration but opening the stands stimulated epicormic sprouting. The results show that thinning in such stands is feasible and provides an option to clearcutting for use under special management objectives. PNW (988).

408. A carefully designed sanitation-salvage-esthetic cutting in a roadside zone in north central California demonstrated that this type of culture in Sierra mixed conifers can enhance their esthetic value as well as their potential for wood products. Because of the "special care" procedures followed, combined logging and slash disposal cost was \$30 a thousand board feet, about twice that of a single tree selection cut in the general forest zone. PSW (989).

409. To reproduce upland central hardwoods most successfully, the harvesting method chosen must create conditions that satisfy the ecological requirements of the species wanted in the new stand. A summary of studies of central hardwoods after harvest cuts, that ranged from single-tree selection to complete clearcutting, shows that heavier cutting favors intolerant species and faster growth of all species. Yellow-poplar reproduction is primarily seedlings, but oaks, hickory, maples, blackgum, sassafras, and dogwood come mostly from advance reproduction and sprouts. These results provide land managers with realistic evaluations of the silvicultural alternatives for the regeneration of upland hardwood forests. NC (990).

410. Dense stands of young ponderosa pine seriously hamper forest management in Arizona and New Mexico. Forty 4-year-old stands, averaging 5,844 stems per acre were thinned to 6 growing stock levels (GSL) representing future basal areas of 30 to 150 square feet per acre. Net dbh periodic annual increment (PAI) was 4.6 times greater at GSL-30 and 2.2 times greater at GSL-150 during the first 5 years after thinning than

the prethinning rate. The PAI of the 100 largest trees per acre showed improvement in diameter, basal area, and volume with increasing growing space. RM (991).

411. The recent controversy over site preparation practices and planting investments on National Forest land in Montana has resulted in certain proposals for natural regeneration of ponderosa pine in this area. A summary of ponderosa pine regeneration and problems in the Northern Rocky Mountain region shows that: 1) natural regeneration usually is slow and frequently uncertain; 2) competition from understory vegetation is intense and usually requires site preparation after cutting for success of natural or artificial regeneration; and 3) planting nursery stock on well-prepared sites can be relied upon to obtain adequate restocking within acceptable time limits. INT (992).

3. ECOLOGICAL RELATIONSHIPS

412. Lack of soil moisture is a limiting factor for successful regeneration in the Southwest. A recent field study of soil moisture availability during the growing season in a clearcut mixed conifer stand in Arizona indicated that the soil moisture deficit approached or exceeded the permanent wilting point only under grass on level and southerly exposures. Adequate moisture was available under burned and scalped surfaces for survival of established seedlings and planted trees throughout the growing season on all exposures. These findings will help forest managers diagnose regeneration problems and prescribe successful treatments in mixed conifer stands where restocking has been difficult. RM (993).

413. Conifer seedlings have invaded large portions of subalpine meadows in the Washington and Oregon Cascades, including many sites where the meadows are key recreational attractions. Fire, grazing, and forest edge effect are possible contributing factors, but the most probable cause is a change in climate beginning in the late nineteenth century and extending into the 1940's. Land managers who wish to maintain the meadow landscapes should be able to control this encroachment by cutting the seedlings. Successional pressures are not great, and a recurrence of favorable environmental factors will probably be necessary before substantial reinvasion of conifer seedlings occurs. PNW (994).

414. Severe soil compaction can result from logging under wet conditions and with heavy equipment on medium- and fine-textured soils on the Atlantic Coastal Plain. Studies in southeastern Virginia indicate that the average time required for severely disturbed soils to recover naturally to normal surface densities is approximately 18 years. Because pine establishment and early growth are greatly reduced on severely compacted soils, forest managers should seek ways to avoid, minimize, or correct compaction damage. SE (995).

415. Mathematical models attempt to accurately describe or predict conditions in or performance of real-world systems. Few models of this

type are available for entire ecosystems. An experiment in modeling southern Rocky Mountain forest ecosystems has yielded a prototype model that integrates selected climatic, edaphic, and topographic factors and relates them to site index of quaking aspen. Although only parts of the model are useful for ecological research in the southern Rocky Mountains, the concepts and methods developed are useful for ecological research in mountain regions generally. RM (996).

416. Delineation of forest stands into environmental classes, and development of land management techniques tailored to fit each class, will permit improved forest management. A classification system using elevation, potential solar radiation, soil type, and plant indicator species (indicators of temperature and moisture conditions) has been developed for forest environments in the South Umpqua Basin in Oregon. Although this system has direct application only to the mature mixed conifer forests in the Basin, the classification technique can be adapted to develop similar classifications for other areas. PNW (997).

417. Shallow water tables underlie some of the most important recreational areas in the Pacific Northwest--the edges of streams, lakes, and reservoirs. A study of the occurrence and radial growth of four tree species on the Olympic Peninsula, Washington, showed that native red alder and western redcedar grew well where stagnant water was less than 15 cm. from the soil surface. Alder and Sitka spruce also grew well where flowing water occurred near the surface, but western hemlock seemed intolerant of all water tables less than 15 cm. deep. If these tolerances are recognized in management decisions, forests of healthy trees can be maintained on the shallow water table areas. PNW (998).

418. Bristlecone pine is one of the oldest living organisms known to man. Studies of these ancient trees in the San Francisco Peaks of Arizona (elev. 9,600 feet) reveal that vegetative buds start swelling early in June, buds burst and active elongation begins in mid June, and male flowers mature and release pollen by late July. This information will aid those who must time their visits to stands of this species with the occurrence of a particular phenological event. RM (999, 1000).

419. The distribution and rates of accumulation of biomass and nitrogen have been determined for 5-, 15-, and 20-year-old alder ecosystems developing on the Tana River flood plain in central Alaska. The mean annual rates of both biomass increment and nitrogen build-up are rapid during the first 5 years, but decrease with increasing ecosystem age. The study contributes to our understanding of ecosystem development, from sandbar establishment through 20-year-old alder stands, within the broader framework of forest succession in interior Alaska. PNW (1001).

(For an additional item relating to II G 3 see paragraph 383.)

H. Remote Sensing Methods

420. Project Fire Scan has been developing infrared fire detection systems since 1962 to overcome limitations of visual detection methods caused by darkness, atmospheric contamination, and the difficulty of finding glowing fires which produce little smoke in early stages. Development procedures required the construction and field testing of an electronic scanning system designed to reliably identify fire targets and determine detection probabilities over a range of forest canopy conditions (open to closed). The present bispectral, or "two-color," system used in combination with well-planned visual detection will result in a more efficient system than visual methods alone. INT (387, 397).

421. An improved bispectral infrared forest fire detection system was field tested in an 8,000-square-mile, Montana-Idaho study area during the 1970 fire season. The new equipment identifies and marks fires as small as 1-ft.² in the forested mountain environment. Approximately half of the fires in the study area were scanned by the airborne equipment and over 50 percent of these were detected. INT (388, 391).

422. Development and testing of a bispectral airborne forest fire detection system indicates a capability of detecting 1-ft.² of burning material (600°C.) against backgrounds ranging from 0° to 50°C. from 15,000 feet. The bispectral infrared system provides a 10:1 improvement in target-to-background signal ratios over the monospectral system. INT (389, 394).

423. A small, inexpensive infrared scanner, designed for light aircraft and helicopters, helps locate small fires detected by the bispectral infrared system. These "fire spotters" are capable of detecting 1-ft.², 600°C. targets at altitudes up to 2000 feet during daytime conditions. The small fire spotters picked up 26 fires in 1970 which would not have been found until later by visual methods. INT (389, 390).

424. Decision rules for controlling an infrared forest fire detection system are derived from simulated detection patrols. These studies provide procedures for determining the most effective operating rules for given budgets. Results are compared to the existing detection system in the Montana-Idaho study area. INT (392, 396).

425. A computer-based model of a small smouldering or creeping forest fire simulates burned and burning areas of a fire at any time after ignition. INT (393).

426. Early tests indicate that a prototype infrared system for observing fire through smoke has advantages and a sensitivity that surpass conventional systems. A comparatively recent development in electronic technology holds promise for providing a practical means for locating and following the progress of forest fires. PSW (395).

427. Small-camera aerial photography determines the volume within a pile of organic material through computer analysis of parallax readings. INT (386).

I. Weather Modification and Weather Effects

428. Modeling of Rocky Mountain lightning storms is enhanced by the modification and testing of two types of mathematical cloud models, the so-called steady-state and time-dependent models. Preliminary results comparing features of real clouds with those of computer-simulated clouds are encouraging. The development of numerical cloud models may produce a new, stronger means of studying the complex physical and electrical interactions of lightning storms. INT (400).

429. Information has been summarized on the worldwide occurrence of lightning, lightning-caused wildland fires, and the ecological ramifications of lightning effects as precursors to forest insects, disease, wind, and fire. INT (405).

430. The large-scale cross section and terrain surface analyses of potential temperature are presented as aids for studying mesoscale and finer weather variations. These analyses, based on a parameter (temperature) that is rarely treated in detail in mountainous terrain, present conditions directly related to airflow near and above the terrain surface. PSW (399).

431. Logging slash outside of smoke sensitive areas can be disposed of by open burning with a minimum contribution to air pollution by controlling time, location, and quantity of fuel. Minimizing air pollution from slash burning requires the effective use of weather forecasts for matching amount of burning to dispersion potential. PSW (398).

432. Causes and methods of predicting strong low-level winds were investigated using data obtained during two wildfires. Results showed that strong winds on these fires were probably a product of several mechanisms in combination. PSW (403).

433. Large losses result mostly from the behavior of fires influenced by such weather systems as fronts, the warm sector of cyclone systems, and sea breeze fronts. Effects of these systems may prevail for only a few hours, may be fairly local, and tend to be under forecasted. SE (407).

434. Calculated values of precipitation effectiveness index and temperature efficiency index for 48 weather observation stations on the Alaska mainland are used to delineate areas that have different climatic classifications during the wildfire season of April-September. The paper outlines procedures, provides maps showing step-by-step analysis and areal boundaries, and suggests possible uses of the information. PNW (406).

435. A simple probability model is used to relate a characteristic space scale measure to point frequencies. The importance of the relationship between scale and predictability suggests the need to define rational scale measures for various weather phenomena. WO (402).

III. IMPROVING TIMBER PRODUCTIVITY AND EXTENDING SUPPLIES

A. Intensive Culture Methods

1. SITE EVALUATION AND SOIL IMPROVEMENT

436. The presence and persistence of epicormic branches can seriously degrade hardwood log quality. In uncut stands in West Virginia large numbers of epicormic branches that appeared during the spring died during the growing season on dominant and codominant red oak and yellow-poplar. Nitrogen, phosphorus, and potassium fertilizers did not stimulate the formation of epicormic branches but nitrogen did increase the vigor and growth of established epicormic branches on the upper sections of the bole. These findings indicate nutrients designed to promote volume growth may be applied without fear of decreased quality through increased numbers of epicormic branches. NE (1002).

437. There is only limited information available about the fertility of virgin forest soils in West Virginia. Research in five locally important forest soils supporting stands containing a high proportion of red, chestnut, or scarlet oak indicated that except for nitrogen, for which there were not clearly defined differences between soils, levels of nutrients are generally associated with the type of rocks from which the soils were formed. Characterizing soil nutrient levels by identifying the soils series and its underlying geologic formation will be useful in oak management and in the design of field experiments in silviculture. NE (1003).

438. Recently devised methods of developing site index curves were used to investigate patterns of height growth in eastern white pine and the impact of these patterns on the estimation of site index. Highly significant differences in the growth curve and its parameters were associated with the quality of the site. Allowing for the changes in growth patterns with the level of site index reduced the average difference between observed and estimated site index from 4.4 feet to 1.0 feet. SE (1004, 1005).

439. Site indices for natural stands of slash pine are determined from reference curves based on an index age of 50 years, whereas present curves for plantations are based on an index of 25 years. Foresters and tax assessors frequently need to equate sites for the two types of stands, but precise conversion values have not been available. Analysis of the most recent yield studies showed that a conversion based on yield is more accurate than one based on height. This led to the development of precise equivalent values at age 25 for 25-year and 50-year sites on the basis of comparisons of cubic yield for planted and natural stands. SE (1006).

440. Broadly speaking, we know that soil physical conditions, available water during the growing season, soil aeration, and nutrient availability regulate forest productivity. Many of the factors that affect these valuables

cannot be measured, neither can they be ignored, so their effects must be estimated. A summary of available research information has been prepared that described various techniques, methods and systems of soils management that may be applied in growing bottomland hardwoods in the lower South. SO (1007).

441. For the Central States, the only site index curves for upland oaks are harmonized curves presumed to be applicable to all oak species. Studies based on stem analysis measurements of black, white, scarlet, and chestnut oaks revealed that these four species have different patterns of height growth and polymorphic height growth patterns for different levels of site quality. The refined site index curves developed for each species provide the practicing forester with an improved tool for intensive culture of the upland oaks. NC (1008).

442. A forest manager often has difficulty deciding which tree species to favor on a given type of land. Comparative studies in some other regions have shown considerable differences in the site index of the same land for different tree species. However, site index comparisons for several hardwood and conifer species in northern Minnesota indicated relatively consistent site-index differences between species at all site qualities. Thus the forest manager has more latitude in that area for adjusting forest composition to meet multiple-use objectives. NC (1009).

443. Intensive management is necessary for rapid growth and development of high-value hardwoods. A recent pot study in Iowa showed that fertilization of black walnut with N, P, and K increased growth only under moist conditions and that nitrogen was the primary element responsible. It is important that adequate moisture be available before fertilizing this species because high rates of fertilization under dry conditions may actually retard tree growth. NC (1010).

444. Height growth patterns for upland oaks are highly variable and standard site index curves often do not accurately describe growth patterns for a given geographical area. Site index curves for white oak and for northern red and black oak growing in the Boston Mountains of northern Arkansas more closely reflect growth patterns than do Schnur's harmonized site curves developed for the entire commercial range of oak. SO (1011).

445. The potential for pine production in much of the Boston Mountains of Arkansas is unknown. Regression equations using elevation, slope, aspect, and organic matter of the surface soil give a practical means of estimating the site index of shortleaf pine for the major soils of this region. SO (1012).

446. Yellow birch develops a very shallow root system in New England forest soils which no doubt restricts tree growth and development. Studies in New Hampshire showed that subsoils deficient in calcium and high in aluminum restricted root and top growth even though the upper soil layers contained adequate nutrients. These results indicate that subsoils may

require limestone and fertilizer additions to develop the vigorous and healthy birch trees needed to maintain adequate wood supplies for local industries. The feasibility of deep fertilization and liming of forest soils remains to be determined. NE (1013).

447. Burning influences the nitrogen (N) fixing capacity of soils because it changes the moisture and temperature regimes. Annual burning of loblolly pine stands for 10 years in the lower Coastal Plain of South Carolina resulted in an average soil N fixation of 1 kg/ha/year, which was ten times the rate on nonburned areas. Many of the samples had much higher rates, and half of the samples fixed little or no N regardless of burning treatment. If the properties of soil which have high fixation rates can be enumerated and the rate of fixation increased by burning or other simple, inexpensive procedures, the need for extensive fertilization may be greatly reduced. SE (1014).

448. The concentration of yellow-poplar roots in the surface horizon in some Hartsells soil profiles in Tennessee suggests that root penetration may be limited by subsoil properties. Research results based on soil analysis, seedling size, and the appearance and distribution of roots within the soil indicate calcium deficiency, aluminum toxicity, or a combination of the two as the limiting factors. This information will help to guide the course of further research on yellow-poplar nutrition and site adaptation. SO (1015).

449. Populations of microfauna in the forest floor (F-layer) depend to a great extent on moisture conditions. A laboratory experiment showed that animals move from a drying forest floor to the underlying mineral soil. Results demonstrate that the surface soil should be sampled along with the decomposing organic matter if the microfauna of a forest are to be measured accurately. SE (1016).

450. The soil mesofauna play an important part in the decomposition process by breaking organic tissue down into particles small enough to be decayed by fungi and bacteria. Fundamental research on the effects of prescribed burning in South Carolina revealed that there was a significant reduction in the soil mesofauna immediately after an annual summer burn. After periodic burning, the mesofaunal population returned to the levels found on unburned plots in less than 43 months. This is the first published report concerning the effect on soil mesofauna of prescribed burning under defined conditions and frequency. SE (1017).

451. California black oak is a potentially valuable species of wide distribution in California and southern Oregon. Site index curves related to aspect and to the site index of a close associate, ponderosa pine, have been developed. These curves should be useful in estimating the growth potential of California black oak in even-aged unmanaged stands in northern California. PSW (1018).

452. A review of recent research on effects of prescribed fire on soil physical properties indicates that if all of the surface organic layer is

consumed by intense fire, drastic changes in macropore space, infiltration, and aeration followed by surface runoff and erosion can be expected in hilly terrain. If burning is used as recommended in southern pines management (e.g., causing only partial destruction of the forest floor), the danger of runoff and erosion is not nearly as great as can be expected from mechanical methods of site preparation or wildfires which would replace prescribed burning. SE (1019).

453. The extensive pine regeneration programs underway in the Southeast require greatly increased production of genetically superior planting stock. Results of 5 years of intensive culture in a slash pine clonal seed orchard in northeast Florida indicate that nitrogen fertilization plus irrigation during the spring increases the number of seed per cone. But irrigation in late summer may suppress both male and female flower development. Clonal lines differ greatly in flowering in response to fertilization and irrigation. This information will help managers to maximize production from slash pine seed orchards. SE (1020).

454. How burning affects soil nutrient levels is a controversial subject. Results of 20 years of annual or periodic prescribed burning in the South Carolina Coastal Plain show that losses of organic matter and nutrients from the forest floor are offset or exceeded by increases of both in the mineral soil. Results indicate that burning neither enriches nor depletes southern soils. SE (1021).

(For an additional item relating to III A 1 see paragraph 370.)

2. ARTIFICIAL REGENERATION

455. Flotation in a liquid of suitable specific gravity is an ideal means of separating full and empty seeds of many coniferous species. Flotation in ethanol caused the viability of spruce pine and slash pine to decline in storage. Drying for 4 hours after soak alleviated this effect for slash pine but even extended drying was only partially effective for spruce pine. It is recommended that flotation of spruce pine seeds be delayed until just prior to use. SO (1022).

456. Several published reports have indicated that planting cottonwood cuttings in auger holes is superior to planting in a planting rod hole. Inserting a 20-inch cutting into a planting rod hole was found to be as effective for establishment and growth of cottonwood plantations as the auger hole method. Results should benefit forest managers in the Mississippi Delta since they indicate no reason to use the more expensive techniques for planting cottonwood. SO (1023).

457. Costs of controlling nursery pests such as diseases, insects, and weeds are often major expenditures in the production of planting stock. Soil fumigation of 2 northern Rocky Mountain nurseries in the late summer with medium to high rates of methyl bromide-based fumigants (170 to 340 lb./acre) has controlled pests, increased seedling survival, and

stimulated the growth of Douglas-fir, western white pine, Engelmann spruce, and ponderosa pine. Seedling production time has been reduced by up to one year at a cost saving of from \$3 to \$4 per thousand seedlings. INT (1024).

458. Both prairie crayfish and short-tailed crickets are predators of pine seed and newly germinated seedlings. Recent studies in central Louisiana have shown that losses are normally small and recommended sowing rates are high enough to offset this predation. Results of these studies have eliminated two suspects as serious predators of direct-seeded pines. SO (1025, 1026).

459. Mechanical site preparation is expensive and should not be used for regeneration unless it can be justified economically. After 14 years, direct-seeded slash pine on disked and furrowed plots in central Louisiana were 2 to 3 feet taller and 0.3 to 0.4 inch greater in diameter than those established on a grass rough. Disking prior to direct seeding slash pine is the preferred site treatment on open grassy areas in the West Gulf Coastal Plain because it increases growth over no preparation and reduces the risk of drought loss inherent in furrowing. SO (1027).

460. Many areas of the South cannot be quickly regenerated by planting because of rising costs and labor shortage or by natural regeneration because of the demand for prompt restocking. Direct seeding has proven to be an acceptable method for obtaining regeneration. A new USDA Handbook brings together detailed management guides for direct seeding longleaf, loblolly, slash, shortleaf, Virginia, and white pines under a broad array of conditions within the South. This technique gives a land manager substantially more options and in many cases greater economy in maintaining full productivity of his forests. SO (1028, 1037).

461. Is the advance reproduction that survives after mechanical tree harvesting in northeastern spruce-fir forests adequate to regenerate the stand? In Maine, after winter logging with a Beloit Tree-Harvester and a rubber-tired skidder, the stocking of surviving seedlings on most of the logged areas remained adequate for the two years of record. Survival was greater off skidroads than on them, and heavy slash accumulations contributed most to both spruce-fir and maple-birch seedling mortality. NE (1029).

462. Because Puerto Rico has no native pines, successful introduction of exotic species would help to broaden the reforestation program. Survival and height growth of nineteen conifer and two broadleaf species in single tree plots indicate that Honduras pine (Pinus caribaea var. hondurensis) grow best on a variety of sites, although several other pines deserve further trial. The trees are still too young to assess wood quality, but the single tree plot techniques has permitted rapid economical testing of a large number of species over a wide range of sites. ITF (1030).

463. Frost heaving causes serious losses to direct-seeded white pines in New England. Forty percent artificial shading during the dormant

season reduced mortality from frost heaving to about one-third of that under full sunlight by reducing incoming radiation during the day and conserving soil heat at night. Direct seeding under a natural vegetation over-story reduces frost heaving and has the additional advantage of maintaining a forest cover during the regeneration period. NE (1031).

464. Steep unstable slopes severely limit the number of regeneration techniques that can be used successfully in the Idaho Batholith. Hand scalping plus a pre-emergence herbicide (simazine) treatment applied in the fall was the most promising of 7 site preparation treatments in terms of cost and effectiveness for regeneration of ponderosa pine. Results verify that site preparation and vegetative control should be used to improve survival and growth of planted ponderosa pine seedlings in this extensive problem area. INT (1032).

465. Pure or nearly pure oak stands throughout the Upper Mississippi Valley may have a scarcity of desirable reproduction after cutting. Trials in southern Wisconsin indicate that the relatively fast growth, high survival, and adaptability of white ash transplants make them the safest selection for interplantings on oak clearcuts. Transplants should be large, with about 2-foot tops, and planting should be accompanied by control of stump sprouting. These findings give the forest manager a reasonable alternative to regeneration of oak in an area where this is very difficult. NC (1033).

466. How long weed control should be continued to maintain good survival of newly planted black walnut is a problem. Research in Iowa and Indiana indicates that at least 2 years of complete weed control is needed for rapid growth and when weeds are controlled for the first 2 or 3 years, trees can be expected to grow rapidly for at least 2 or 3 additional years after weed control is discontinued. Application of these findings is important to the success of walnut plantings. NC (1034).

467. Although there are some 30,000 acres of cottonwood plantations in the lower Mississippi Valley, the effect of initial tree spacing on growth is unknown. Research near Fitler, Mississippi, provided stand and growth information at 4 spacings (4X9, 8X9, 12X12, and 16X18 feet). With present utilization standards, the 12X12 spacing appeared to be the best. It produced 18 cords of merchantable wood in 7 years and an average annual diameter growth of one inch. SO (1035).

468. Natural regeneration of lodgepole pine is sometimes limited by intensive competition from understory vegetation and a dearth of serotinous cones that usually supply adequate amounts of seed. On such areas of regeneration other methods are needed. Hand-prepared, 12-inch-square, scalped seed spots yielded 72 percent stocking of lodgepole pine on slopes less than 45 percent in the Abies/Vaccinium habitat type in Wyoming. Results demonstrate that it is feasible to direct seed lodgepole pine on high elevation (7,900 ft.) sites in Wyoming. INT (1036).

469. It is often difficult for a small landowner to understand how he can make a continuous profit from his woodland. An understocked 30-acre loblolly pine woodlot in Georgia was managed for 20 years by cutting and replanting one acre each year. During the 20-year period of management, basal area on the average merchantable acre increased from 28 to 88 square feet, while an average annual harvest of 22 cords was obtained per acre harvested. SE (1038).

470. The Southeastern Area for State and Private Forestry will soon distribute limited numbers of cuttings from clones of eastern cottonwood selected for pulpwood and timber production in the lower Mississippi River Valley. To produce sufficient numbers of cuttings for field planting, nurserymen will have to propagate vegetatively the cuttings they receive. Mist propagation has proven reliable for expanding cottonwood clones in experimental and production nurseries in the mid-South. The procedure is relatively inexpensive and the equipment necessary need not be elaborate. SO (1039).

471. Today a hardwood plantation is a rare sight in the southern Appalachians but a recent summary of research results shows that such valuable species as yellow-poplar, black cherry, black walnut, and some oaks can be planted in the region with considerable success. The potential of assured regeneration of the fine hardwoods can do much to promote intensive forest management for the benefit of the rural economy. SO (1040, 1041).

472. Airlayering is a useful technique for the establishment of genetically uniform plants for research and the multiplication of selected germ plasm, but little information is available on the long-term growth and development of the resulting trees. Studies in northeastern Florida revealed that 12-year-old airlayers of slash pine rooted nearly as well as trees grown from seed, and that they had equal root surface areas but no tap root. Stem growth was the same, indicating that trees grown from air-layers perform as well as seedling stock. SE (1042).

473. The high number of direct seeding failures in northwestern California indicates the need for a better understanding of Douglas-fir seeding requirements. Research on the Klamath and Six Rivers National Forests showed that seed should be sown in November or December and better seedling establishment will occur on fine-textured red soils than on coarser grey-brown soils. PSW (1043).

474. Genetic crosses between American and European poplars (Populus spp.) produced many promising hybrids. As part of a regionwide test of these hybrids, 50 clones were outplanted on well-drained, alluvial sites in West Virginia. Over a 20-year period, the five best clones averaged between 0.4 and 0.5 inch annual diameter growth and 3.5 to 4.0 feet annual height growth. Since these hybrids are easily propagated by cuttings and will grow rapidly on bottomland sites, they may be useful in stabilizing streambanks and reducing siltation in streams. NE (1044).

475. In Hawaii, selection of tree species for reforestation may be a serious problem because of wide differences in climate and soils. Results of adaptability tests of several tree species indicate that Nepal alder, blackwood Acacia, Java podocarpus, and native koa have desirable characteristics for reforestation. Planting trees on marginal and abandoned pasture and cultivated lands in Hawaii could increase their economic value through production of timber, improved watershed conditions, and scenery. PSW (1045).

3. STAND IMPROVEMENT

476. There is an urgent need for herbicides which are as effective as foliar sprays of 2, 4, 5-T but less hazardous to the environment. Formulations of dicamba and picloram, alone or in mixture with 2, 4, 5-T, effectively controlled stands of mixed hardwoods in central Louisiana when applied at the rate of 1 to 2 pounds per acre. However, loblolly pine was more susceptible to these sprays, restricting their use for pine release. SO (1046).

477. There has been no way to determine success of foliar spraying for brush removal earlier than one year after treatment. Ten years of experimentation with more than 50 herbicidal formulations in central Louisiana showed that unless a herbicide initially defoliated at least three-fourths of a hardwood tree crown, there was a 95 percent chance that later topkill would be unsatisfactory. SO (1047).

478. Selective thinning of pine plantations often cannot be justified because of rising costs of marking and harvesting individual trees. A 15-year test with loblolly pine in southern Arkansas showed that a combination of row and selective thinning permitted mechanical harvesting plus the silvicultural advantages of selective thinning without sacrificing yield. SO (1048).

479. Salmonberry and thimbleberry are troublesome brush species that quickly occupy forest land after logging or wildfires in Coastal Oregon and Washington. Herbicides are needed that will give long-term control without damaging young trees. Low volatile esters of 2, 4, 5,-T appear to be more effective than amitrole-T and less expensive than mixtures of picloram and phenoxy herbicide amines when used as midsummer foliage sprays. PNW (1049).

480. Many hardwood species are resistant to herbicides currently in use. Researchers in Louisiana observed additive effects in absorption and lateral and downward movement of a combination of 2, 4, 5-T ester and dicamba applied to sweetgum, water oak, red maple, and loblolly pine. This mixture makes an effective spray which contains lesser amounts of any one phytotoxin than is possible when only one herbicide is used, thereby reducing the concentration of a potentially hazardous chemical in the ecosystem. SO (1050).

481. Douglas-fir does not occur naturally in Alaska. The results of several introductions of this species in southeastern Alaska during the last 40 years show that it is capable of germinating, becoming established, making excellent growth, and producing viable seed more than 200 miles north of its natural range on the coast. This suggests that Douglas-fir may have future silvicultural value in this area. PNW (1051).

482. High-quality southern hardwoods grow rapidly on river and stream bottoms and other moist, rich sites in the Coastal Plains, true swamps, and loess bluffs, and are extremely diverse in species, wood quality, and uses. Research findings on protection, thinning, planting, natural regeneration, harvesting systems, utilization standards, and other factors entering into management decisions have been synthesized for the forest landowner interested in increased returns from management. SO (1052).

483. An effective soil herbicide could be very helpful in controlling cull hardwoods. Of three soil herbicides (bromacil, picloram, fenuron) applied to clayey soils of central Louisiana, only bromacil satisfactorily killed blackjack and post oaks. Best kill was obtained by using 2 grams per inch of trunk diameter spread uniformly around the base of each tree during the period March to June. SO (1053).

484. Undiluted 2, 4-D amine is the standard chemical used to kill weed trees; however, it is not fully effective on a few resistant species. Mixing Tordon with 2, 4-D is more effective than 2, 4-D in winter. It also permits year-around control of blackjack oak, mockernut hickory, and sweetgum, species resistant to 2, 4-D amine, and saves labor through wider spacings between injections. SO (1054).

485. Because of the lack of information on the behavior of cull trees, the usual procedure in timber stand improvement work has been to treat every living cull tree. Research in West Virginia showed that 57 percent of poor-vigor culls and 27 percent of the overtapped culls died within 7 1/2 years after a partial cutting. The remaining trees in these two classes did not require treatment. Treating only culls that have an adverse effect on the stand can result in appreciable savings to owners practicing intensive forestry. NE (1055).

486. Precommercial release of crop trees can improve species composition, stand quality, and tree growth. Practical guidelines developed for even-aged Appalachian hardwood stands indicate that crop-tree releases (1) should be postponed until the stand is 9 to 12 years old; (2) should be done with hand tools by a carefully trained woodsman; and (3) that selection among crop-tree species that need light should be restricted to dominant and codominant stems. Earlier treatment was partially ineffective because of the rapid regrowth of trees and vines in younger stands. NE (1056).

487. When Appalachian hardwoods are clearcut down to a 5-inch diameter limit, a number of living unwanted stems less than 5 inches are

left standing. A comparison of basal spraying and power saw felling for eliminating these stems indicated that felling with the power saw was 30 percent cheaper, 100 percent effective in removing the offending stems, and left the area much more acceptable esthetically. NE (1057).

(For an additional item relating to III A3 see paragraph 5.)

4. ANIMAL DAMAGE

488. Pocket gophers occupy many acres of wild land in the western States, and are known to damage and kill several conifer species. A study in south-central Oregon revealed that losses of planted ponderosa, Jeffrey, and lodgepole pines were nearly identical, that damage occurred predominantly during the winter, and that two-thirds of the experimental plantation was destroyed within 3 years. Thus it does not appear possible to minimize damage by planting one of these species in preference to the others. Also, control measures to reduce gopher numbers should be scheduled just before winter, and plantations in area infested with these animals are probably doomed unless effective protective measures are undertaken. PNW (1058).

489. Safer chemicals are being sought to replace endrin (a chlorinated hydrocarbon) as a coating to protect conifer seeds from seed-eating rodents. In Washington, bioassays using deer mice showed that R-55 (a thiocarbamate derivative) was ineffective as a protective coating, but mestranol (an antifertility chemical) reduced Douglas-fir seed consumption to levels comparable with endrin. Continued research on mestranol and similar compounds is called for, although even if proven environmentally acceptable and effective in the field, the current high cost of mestranol may make its use uneconomic. PNW (1059).

490. Predation may be extensive if repellent-treated seed are sown too early in the season. A recent study in central Louisiana showed that loblolly pine and slash pine seeds exposed to 45 days of weathering may lose up to 70 percent of the endrin protective coating. Direct seeding should be scheduled to minimize the time between sowing and germination, so as to insure that effective amounts of the repellent are retained on the seed. SO (1060).

491. Although direct seeding of Douglas-fir in the Pacific Northwest can be done successfully by coating the seeds with endrin to protect them from seed-eating rodents, many operational seedings still fail. An experiment in Washington revealed that some seeding failures could be due to insufficient endrin on the seed because of inadequate seed treatment, and to endrin losses during aerial dissemination and weathering. In addition, the study suggests means for improving treatment, and points to the importance of chemical analysis in evaluating safer chemicals to replace endrin. PNW (1061).

492. Ponderosa pine seed development and survival studies in northwestern Montana showed that small forest animals utilize 24 out of 25 seeds that reach maturity. Red squirrels use about two-thirds of the seeds while deer mice, chipmunks, and birds consume the remaining one-third. Results show the dependence of animal populations on conifer seed production and the severe potential impact of some animals on forest regeneration. INT (1062).

493. Following harvest cutting, natural regeneration of ponderosa pine in western Montana frequently is slow and uncertain. The major factors causing this poor regeneration are cone abortion, squirrel cutting of cones, and rodent destruction of seed on the ground. A landowner can reasonably expect to control: 1) most squirrel depredations by banding seed trees, 2) 50 percent of the seed losses on the ground by controlling seed eating rodents, and 3) 50 percent of the first-year seedling losses by thorough site preparation. INT (1063, 1064).

5. GROWTH REQUIREMENTS

494. Upland species usually grow slowly when planted on wet sites. Root respiration (an important growth process) of upland species, loblolly pine and yellow-poplar, was nearly twice as high as that for lowland species, weeping willow and river birch. Comprehensive information of this type contributes to our understanding of why and how species adapt to particular sites. SO (1065).

495. Protracted flooding frequently reduces growth of southern pine seedlings. Flooding for 21 weeks during the dormant and early growing season depressed loblolly pine seedling growth 15 to 26 percent whereas flooding for 7 weeks during the dormant season caused no loss in growth. Owners of forest lands subject to frequent flooding which does not inundate terminal buds can anticipate marked loss in growth if continuous flooding occurs during the growing season but little or no loss from brief dormant-season flooding. SO (1066).

496. If sugar maple seed are collected from the tree too soon, they will not germinate; but if collecting is delayed too long, they will be shed from the tree. Recent studies have shown that sugar maple seeds generally reach their maximum germination potential when the moisture content has dropped below 145 percent (dry weight basis) or the samaras have turned a yellowish green color. This information will enable seed collectors to gather sugar maple seeds at the right time and be assured of at least 95 percent germination. NE (1067).

497. Pine seedlings planted on pumice soils in central Oregon frequently grow slowly. Results of an experiment with lodgepole and ponderosa pine seedlings grown in boxes containing representative soil profiles indicate that both the physical and nutrient characteristics of the pumice layer may limit seedling development in the field. This suggests that auger planting, which has been effective on these soils, may be superior

to machine planting because the auger breaks up and mixes the pumice layer with material above and below it. PNW (1068).

498. The needle concentration of minor elements, necessary for optimum Monterey pine growth is not known. A PL 480 project in Spain delineated zones of deficiency, sufficiency, and toxicity for iron, zinc, and copper in the needles of Monterey pine seedlings. Optimum growth occurred when there were 40 to 150 parts per million (ppm) of Fe, 10-200 ppm of Zn and 2-8 ppm of Cu in the needles. Visual deficiency and toxicity symptoms were also described. These findings are important in the attempt to quantify field nutrient levels in this valuable species. WO (1069).

499. The relationship of chlorophyll content to photosynthesis in developing leaves is not well understood. Selected biochemical factors associated with photosynthesis were investigated in the expending leaf zone of young cottonwood plants in controlled environment rooms. The photosynthetic mechanism of newly formed leaves is inoperative until critical levels of Calvin cycle enzymes are synthesized, even though considerable total chlorophyll may be present. This demonstrates the importance of protein metabolism to the onset of photosynthesis during leaf expansion in cottonwood. NC (1070).

500. The physiological, biochemical, and anatomical correlations between leaf and stem growth in the zone of leaf development are not well understood. Changes in nitrogen content and soluble protein, and peroxidase patterns as determined by electrophoresis were compared for leaves and internodes below the growing tip in eastern cottonwood in Wisconsin. These biochemical parameters were found to be closely related to changes in organ size and physiology. Such research in basic physiology provides new insights into the roles of various biochemical substances during the period of rapid development in plants. NC (1071).

501. Mycorrhizae, the symbiotic union of selected soil fungi and tree roots, are essential for vigorous and healthy growth of many forest tree species. Proceedings of a recent conference on this subject summarized the current information on this complex relationship. It is apparent from numerous investigations of a number of different mycorrhizal relationships that mycorrhizae increase tree growth by increasing nutrient content through greater absorption of infected roots and by increasing the utilization of the less available forms of minerals. Such information is proving valuable in improving our planting procedures, especially with nonnative species, where the mycorrhizal fungi may have to be added at time of planting. WO (1072).

502. Fertilizers are used in Christmas tree plantations to stimulate rapid growth and to promote a luxuriant green foliage. Research in North Carolina showed that planted 3-year-old Fraser fir and white pine can be fertilized with ammonium nitrate at the rate of 1 ounce for small trees and 2 ounces for trees more than 4 feet tall. Larger quantities resulted in excessive nitrogen concentration in the foliage (4 to 5 percent) and killed the trees. SE (1073).

503. Some physiological studies in plants require accurate identification of the comparative stage of development of vegetative tissues between different individuals. Growth models were developed for eastern cottonwood in Wisconsin that mathematically relate leaf length, leaf area, leaf dry weight, number of vessels per internode, and number of vessels per petiole to a previously developed quantitative index, the plastochnon index that defines the relation between physical measurements and other growth events or processes. These models can be used to adjust plants of different developmental stages to a standardized morphological time scale and to predict developmental processes and events from simple, nondestructive measurements. NC (1074).

504. Under present regeneration techniques many species are grown on a wide variety of sites. Potted 1-year-old loblolly pines had the same distribution of dry matter under environmental conditions ranging from one-third to full sunlight. However, soil moisture stress appeared to inhibit shoot growth to a greater degree than root growth. Results suggest that loblolly pine trees adapt well to changing environments. SO (1075).

505. Plant response often varies with season of fertilizer application. Three-year-old slash pine seedlings grown in potted Beauregard silt loam responded equally to fall and spring applications of nitrogen in terms of height growth, total weight, and nitrogen recovery. These results suggest that season of application is not a critical factor in nitrogen nutrition of slash pine. SO (1076).

506. Forest tree nurseries producing Douglas-fir seedlings in Oregon and Washington often apply nitrogen fertilizers to improve growth. An experiment at the Webster State Forest Nursery near Olympia, Washington, showed that seedling growth in the nursery, and performance after outplanting, were better when the nitrogen was supplied in the form of urea or nitrate rather than as ammonium. Choice of the nitrogen source is therefore clearly evident, but because of the complexity of other related factors, each nursery should determine the best fertilization regime to use by making an on-the-site investigation. PNW (1077).

507. It is difficult to study the annual formation of xylem because of high variability among individual cells within a tree and the effects of cell damage due to sampling technique. Research in Poland (PL 480) shows that the effect of cell variability is greatly reduced if samples are taken from several trees instead of a single specimen and averaged for analyses. When studying xylem formation of Scots pine throughout the season, the effects of previous wounding (through sampling) on cells are avoided by taking samples at least 1 cm apart at intervals up to 21 days. WO (1078).

508. Plants vary in their efficiency to transform CO₂ into organic matter. A research team (PL 480) found that two ecotypes of Scots pine, originating from highland and lowland regions of Poland, exhibited different patterns of dry matter production, photosynthesis, and respiration. Results also supplied information on the different patterns of needle

growth in the top, middle, and basal parts of shoots. This information aids in the interpretation of data on physiological processes occurring within a plant and is important for sampling representative needle material. WO (1079).

6. GROWTH AND YIELD

509. The role of thinning is changing in the management of slash pine. In this short-rotation species, mean annual increment culminates from 25 to 27 years of age in stands of 500 trees per acre or less. Primary product objective should determine initial spacing, and thinning under this condition assumes little importance as a regulator of growth in rotations up to 30 years. This concept is important for the management of superior trees because they are too valuable to plant at spacing that requires early thinning. SE (1080, 1081).

510. In unmanaged second-growth stands, codominant and intermediate yellow birch poles are usually crowded out by more dominant species. Through moderate to heavy crown release, diameter growth and crown vigor of these trees were greatly improved. Epicormic branching was also increased by release but was not serious because most of it occurred above the butt log. These results can mean more valuable yellow birch sawlogs for the birch-using industry. NC (1082).

511. Suitable volume tables were lacking for the two cedars of southeastern Alaska--western redcedar and Alaska-cedar. Separate cubic-foot volume tables and combined board-foot tables are now available for old-growth stands of these two valuable species. PNW (1083).

512. Since most old-growth northern hardwood timber in New England has been cut, future timber supplies will come from second-growth even-aged stands. How will financial yields change? A clearcutting in 90-year-old even-aged northern hardwoods produced a variety of products with delivered value of \$758 per acre. Clearcutting a nearby uneven-aged, old-growth stand produced \$688 per acre. Even-aged stands containing high-quality paper birch in mixture with species of low quality will peak in product value when the short-lived paper birch mature. Thus financial yields from old-growth stands can be equalled or exceeded by yields of much younger even-aged stands that followed clearcutting. NE (1084).

513. Knowledge of primary productivity of coniferous forest ecosystems is important for determination of nutrient cycling and storage within the systems. A 26-year-old western hemlock stand on the Oregon Coast had a total biomass and current net annual production of 231.1 and 36.2 metric tons per hectare, respectively. Of the total mass, 65 percent was in stems, 9 percent each in the leaves and branches, and 17 percent in the roots. This production rate is high when compared with other forest types analyzed in eastern Asia and other parts of the world. PNW (1085).

514. Western larch is an important species in the Blue Mountains of northwestern Oregon, but there is little information available to guide thinning operations in pole-sized stands in this area. The 5-year growth responses of a 32-year-old pure even-aged western larch stand thinned to a wide range of stocking levels showed that maximum merchantable volume growth was reached at a basal area of about 90 to 100 square feet per acre. The results of this study can be used to derive preliminary guidelines on the stocking to leave after the first thinning in such stands. PNW (1086).

515. Treefern is a major component of rain forests in Hawaii. Studies of the growth habits of the most common treefern, hapu'u-pulu, indicate that its annual rate of growth is much slower than reported earlier--less than 0.1 inch in diameter and less than 2.0 inches in height. Forest protection and management activities should recognize that if we hope to maintain this resource, much longer rotation cycles will be needed than previously thought feasible. PSW (1087).

516. New management guides were developed to maximize recoverable growth in vigorous, mature (70 to 150 years), even-aged, Douglas-fir stands in western Oregon and Washington--a class of stand that will probably exist for another 50 years. Through intermediate harvest cuttings, it was possible to recover 81 percent of the potential growth (net growth plus normal mortality) for up to 38 years from single thinnings and for 18 years with two thinnings. Thinning resulted in substantial reduction in losses caused by bark beetles (61 percent), windthrow (30 percent), breakage (33 percent), and suppression (46 percent). Thinning in this forest type should extend into the upper crown canopy, and should leave 60 to 85 percent of normal basal area. PNW (1088).

7. FOREST MEASUREMENTS

517. The accuracy of two optical dendrometers (Zeiss telemeter tele-top, Barr and Stroud) were compared with measurements taken by climbing loblolly pines in central Louisiana. Estimates of tree volume, surface areas, length, and sum of diameters for entire tree did not differ significantly from caliper measurements. Both dendrometers overestimated measured volume by about 1 percent. SO (1089).

518. Foresters often need quick reliable estimates of stand volumes. A stand volume equation is now available for even-aged lodgepole pine stands in Montana and Idaho. The equation ($V = 0.46952 [BH] - 32.79$) gives direct estimates of total gross cubic-foot volume (V) of stands from measurements of stand basal area (B) and average height of dominant trees (H). INT (1090).

519. Forest researchers and managers are constantly in need of better ways to estimate standing timber. In a recent study of alternative relative measures of stand density for Pacific Northwest Douglas-fir, a simple sum of diameters to a fixed power ($\Sigma D^{1.55}$) when used alone, provided

the simplest of several diameter-based measures. Unlike basal area, it has a direct biological interpretation as a sum of expected tree areas per unit of forest area. This power function can be used as a measure of stand density which does not require concurrent determinations of age, site index, or average diameter. PNW (1091).

520. A modified computer program (STX 1-11-71) for processing dendrometer measurements of standing trees is now available. It allows combining 3P sampling and dendrometry with multistage sampling where first stage may involve area sampling or point sampling. It also substitutes a Fortran sort for system sort/merge and provides for within-tree sorting and subtotaling by quality grades. The new program will facilitate the analyses of tree measurement data. SE (1092).

521. Although leaf surface area is an important indicator of tree growth, accurate measurements have been difficult to obtain. Regression estimates of the needle-area growth of loblolly pine were obtained from periodic measurements of the green length and the average fascicle length of the foliated portion of individual branches. This technique is nondestructive and applicable to physiological studies of any conifer. SE (1093).

522. Sample selection of individual logs with probability proportional to predicted volume (3P) in three tests of log scaling indicated coefficients of variation for logs of 17 to 27 percent. This suggests that 3P log scaling may be efficient in providing precise estimates to total volume at small cost, and it may prove superior to sample log scaling methods now in use. PNW (1094).

523. Yield tables commonly available for black spruce have in the past been inadequate to reflect the productive potentials of even-aged stands growing on typically organic soils in northern Minnesota. New yield tables are now available which describe the growth and yield relationship of Minnesota black spruce to site index, age, and basal area density. This will permit more accurate forecasting of growth of this useful species. NC (1095).

524. Present yield tables are not adequate estimators of quaking aspen growth and yield. To assist in the management of this species, new yield tables applicable to aspen in northcentral Minnesota have been established which provide equations for predicting total cubic foot volume, ratio of merchantable volume to total volume, and future stand diameter, height, and basal area. These yield tables also include information for total stand volume and merchantable stand volume to 3- and 5-inch top diameters. NC (1096).

525. Sampling with unequal probabilities of selecting a sample unit frequently can result in increased efficiency in estimating population totals. To facilitate drawing samples using this method, a computer subroutine is provided that identifies the units in the sample, calculates their sampling probability, and summarizes the distribution of this probability over the entire population for use in subsequent estimates of the population

total and its variance. This procedure has improved the efficiency of surveys of insect damage, of tree defects, and of compartments used in timber management planning. INT (1097).

526. Rounding the independent variable in linear regression will generally bias the least squares estimators of the regression coefficient. A rule for rounding has been derived to retain sufficient measurement precision so that the resulting bias will be negligible. SE (1098).

8. MANAGEMENT PLANNING

527. A new management guide for black spruce in the Lake States was published in Minnesota. Summaries of information on soil site relations, associated vegetation, methods and requirements for reproduction, stand development, yield and 10-year net growth, and damaging agents are provided. It also includes recommended management practices for pulpwood and Christmas trees stands, and requirements for successful broadcast burning. NC (1099).

528. Data relating the effect of site, initial spacing, and age to growth and yield of slash and loblolly pine are sparse for cutover areas in the West Gulf Region. Basal areas, cordwood and cubic foot volumes, average dbh, and diameter distribution are summarized by spacing-site index categories for 14-year-old slash pine and 17-year-old loblolly pine planted in central Louisiana. Results can be used to select optimum planting densities for various sites and management objectives and in projecting plantation growth and rotation length for various products. SO (1100, 1101).

529. Yield tables for managed stands are essential guides for forest managers. Improved field procedures and computer programs have been developed for ponderosa pine in the Black Hills of South Dakota and Wyoming to meet the need for more realistic simulations of stand growth, response to intermediate cuttings, and reproduction cuttings by any of the even-aged management systems. RM (1102).

530. A comprehensive procedure for computation of yield tables for dwarf mistletoe-infested, managed, even-aged stands of lodgepole pine in Colorado and southern Wyoming has been developed to help forest managers evaluate and choose between the alternative practices of sanitation thinning, no treatment (with hope that the stands may eventually become merchantable) or stand destruction and regeneration. RM (1103).

531. Expanding use by the public, coupled with the need for increasing amounts of wood, requires intensified management of oak forests. Neither of the standard management systems--selection cutting or even-aged management by large blocks--is acceptable for all purposes. Group selection is applicable on small woodlands, but on large holdings the system would have to be modified to provide for large groups to be identified, treated, and controlled by areas, and with the cut regulated by volume.

Research is needed to develop and demonstrate a system that has the advantages of group selection cutting but that will also adequately provide for orderly regulation of yields--not just for timber but also for water, wildlife, and all other products of the forest. NE (1104).

9. MAPLE SYRUP PRODUCTION

532. The selection and propagation of sugar maple trees superior in sap sugar concentration is of primary importance to the future of the maple syrup industry. Forty-four sugar maples have been tested and selected from among 21,000 trees growing from Maine to Pennsylvania and are now being clonally propagated and are growing in the Burlington, Vermont, area. These trees with sap sugar content as high as 10.6 percent will form the basis for future progeny and clonal tests for superior selections and for the establishment of sugar maple seed orchards. NE (1106).

533. It would be useful to the maple syrup industry if high producing sap trees could be easily recognized. When a number of characteristics of individual sugar maple trees were measured during one season, both sap volume yield and total sugar production were correlated with tree and crown size. But contrary to popular belief, there was little evidence of a relationship between tree characteristics and sap sugar concentration, an essential factor for the low-cost production of maple syrup. NE (1105).

534. Maple syrup producers have long needed information relating to the optimum stocking of sugar maple trees for sap production. A sugarbush stocking guide has now been prepared which suggests the minimum number of trees per acre for sugarbush stands of various diameter classes that will allow for maximum crown development. The guides are designed for use in developing sugarbushes from forest grown stands, for thinning in existing over-crowded sugarbushes, and for spacing recommendations in planting new sugarbush stands. NE (1107).

10. NAVAL STORES

535. A tree breeder interested in manipulating the monoterpenes composition of longleaf pine and slash pine oleoresins can now be assured of some degree of success. Recent genetic studies of the monoterpenes of both clonal and control-pollinated individuals of these species demonstrated that the composition of cortical oleoresin is under strong genetic control. By careful selection and breeding of trees high in selected desirable monoterpenes, it will be feasible to both modify and improve the composition of the oleoresin. SE (1108, 1109).

536. Levopimamic acid is a potentially useful chemical occurring in the oleoresin of slash and longleaf pines. Recent studies with slash pine have shown that high oleoresin yielders tend to have a high levopimamic

acid content. It is thus feasible to increase both the oleoresin yields and levopimaric acid content in the same genetic improvement program by screening only the high oleoresin trees for levopimaric acid. SE (1110).

537. The difficulty of obtaining cortex resin for comparative studies in species variation from corkbark fir (A. lasiocarpa var. arizonica) led to an attempt to determine whether phloem and cortex resins are sufficiently alike to analyze together. The two kinds of resin proved to be similar qualitatively but quantitatively different, with cortical resin generally higher in limonene and lower in the other components. It can be concluded that resin from the two tissues should be analyzed separately in future chemosystematic studies. PSW (1111).

B. Breeding Improved Trees

1. DISTRIBUTION AND CLASSIFICATION OF FOREST TREES

538. Taxonomy and nomenclature of the Pinus flexilis complex, an important group of forest trees in the West, has remained conjectural for many years. On the basis of new detailed observations on herbarium specimens and seedling tests, this group can be divided into two species P. flexilis James on the North, and P. strobiformis Engelm. on the South. This information is of importance to the resource manager in selecting the correct species for planting in the Southwest. INT (1112).

539. The vegetation of many parts of California has changed dramatically in the last few decades through natural succession, logging, and urbanization. Fifty-seven elevational profiles of nearly half of the State's vegetation as it existed in 1930 have now been assembled. Beside providing a useful historical record, the profiles illustrate the influence of such ecological factors as elevation, exposure, slope, and maritime influence on the composition of the dominant vegetation. To the resource manager, this is a useful history for future land use planning. PSW (1113).

540. A comprehensive handbook has been compiled which describes and illustrates the 33 trees and 94 shrubs native to Alaska. Also included are range maps, a key for identification of the woody plants during summer and winter, and a large color map showing the types of tundra and forest. It will be a valuable reference for anyone interested in the preservation and wise use of Alaska's natural resources. PNW (1115).

2. INHERENT VARIATION

541. Recent reports from southern Mississippi, Louisiana, and Arkansas suggest that the incidence of dwarfing could be a limiting factor in slash x shortleaf pine hybrid breeding programs. Current investigations

have shown that dwarfing was affected by shortleaf pine pollen source, but on the basis of available evidence dwarfing was probably a consequence of hybridization rather than the combination of genes for dwarfing. Though serious to the tree improver, the dwarfing problem now can be largely eliminated by standard nursery grading procedures which select only normal seedlings for planting. SO (1122).

542. When trees from distant seed sources are planted, they do not have the same growth rate as those from local parents. Recent remeasurement of test plantings of ponderosa pine from different elevational sources established in 1938 have shown that specific gravity decreased as elevation of parents increased and when ponderosa pine from any source is planted at high elevations in the Sierra Nevada, the wood will have lower specific gravity. These results suggest that midelevation sources outplanted at about 3,000 feet could give the desirable combination of high volume yield and high specific gravity wood. PSW (1117).

543. An analysis of enzymes from germinating pine embryos revealed certain enzymes that are inherited as single genes. These enzymes which can be easily identified are now being used as "genetic markers" in studies of gene migration and natural selection in natural forest tree populations. Such studies clarify the mode of inheritance in forest trees and provide guidelines for future breeding programs. PSW (1116).

544. Seeds produced from self-fertilization tend to produce slower growing seedlings. Therefore the degree to which coastal Douglas-fir can set sound seed following self-pollination is an important factor in managing seed orchards of this species for the mass production of improved seeds. Following controlled pollinations, self-fertility was found to be generally low, with the median tree yielding 7.5 percent as many seeds following self- as following cross-pollination. This low level of selfing should pose no serious problem to the seed orchard manager. PNW (1125).

545. Knowledge of the variation in selected wood characteristics of sweetgum provides the tree breeders with important tools for developing an improvement program for this species. Recent investigations with first-year seedlings from different geographic sources, grown under controlled conditions, demonstrated that fiber tracheid length was longest, and wood specific gravity was lowest in sources from the lower latitudes. These population differences suggest the feasibility of modifying wood quality through genetic manipulation of selected seed sources. WO (1127).

546. The diverse conditions under which Norway spruce grows suggest a great amount of genetic variation in this useful European species. Studies in Poland of 25 local Polish seed sources found considerable variation in seed size, weight, and mineral content, as well as marked differences in seedling growth and mineral requirements. Both elevation and latitude were correlated with mineral content and seedling growth. With further testing, guides for the selection of seed sources best suited for the United States can be developed. SO (1118, 1119).

547. There is an urgent need for higher production of quality wood on short rotations for reconstituted wood products, veneer logs, and saw-timber. To meet this demand will require trees such as hybrid poplars with inherently rapid growth to justify much more intensive culture than has been economically feasible in the past. The distribution, taxonomy, variation, and site requirements of eastern cottonwood are now summarized and evaluated for those planning to use this species. NE (1123).

548. To meet the increasing demand for hardwood fiber, the cultivation and management of faster growing hardwood varieties, as hybrid poplars, is taking on new importance in the United States. Two Italian scientists have now demonstrated that superior poplar hybrids have a longer growing period, higher photosynthetic rate, and a relatively smaller number of large vessels than their slower growing parent species. Collectively, these features of hybrids could account for their superior growth. This information will aid in the more rapid identification of superior trees for the poplar improvement program in the United States. WO (1126).

549. Trees selected for vigor and form can also serve as a basis for an oleoresin improvement program. Studies of slash pine showed that high oleoresin yields were positively correlated with tree vigor. It would be possible and desirable in future programs to select high oleoresin yielding trees from trees originally selected for vigor and form, thus possible gains in all three traits could be obtained with a common selection program. SE (1121).

550. To obtain greater wood volume on fewer acres, it would be desirable to be able to select and grow tall stocky trees. Recent tests with ponderosa pine seedlings suggest that this may be possible. Diameters at average seedling height of 12.5 inches among 41 families were 22 percent greater from stocky parents than from slender parents, though average heights were not significantly different. These investigations are being continued to determine if this relationship remains true for the adult types. PNW (1124).

551. The importance of racial variation is often overlooked in regenerating slash pine within the species range. Growth results from 15 out-plantings of 69 seed sources show that seed for planting slash pine in areas north of central Florida should be collected mainly in South Georgia. Selection for oleoresin yield and resistance to fusiform rust may best be accomplished through selection of individual trees. SE (1120).

3. INSECT-DISEASE RESISTANCE

552. Brown spot needle blight is a serious seedling disease that prolongs the grass stage of longleaf pine and discourages the regeneration of this valuable species. Approximately one-third of 227 plus-tree progenies from wind pollination, grown for 2 years in central Louisiana, showed strong evidence of resistance to brown spot. Selected trees showed a high degree of disease resistance and will be useful in tree breeding programs. SO (1128).

553. Profitable management of slash and loblolly pines depends upon incorporating rust resistance into otherwise improved planting stock. Phenotypic selection in heavily damaged stands is an efficient means for locating new sources of resistance. When this concept was recently tested, progenies from all rust-free parents were more resistant than seedlings representative of the general population. Additional resistance can be obtained by progeny testing of these initial selections. SO (1129).

554. A decade ago breeding for resistance was considered only a promising means of reducing losses to forest insects and diseases. Convincing examples have since demonstrated its practicality, and a summary and evaluation of recent accomplishments and descriptions of their implications with special emphasis on southern pine resistance to fusiform rust has been prepared. On the basis of these evaluations, new approaches and areas of research meriting increased effort can be recommended for consideration by research managers. SO (1130).

555. In the South, the need to produce more timber at lower cost on fewer acres has led to increasing use of intensive cultural practices such as site preparation, cultivation, and fertilization. Although these practices increase growth, they have also been shown to increase the incidence and severity of fusiform rust in slash pine. Recent studies have demonstrated that regardless of cultural treatment, the more resistant strains within the species remained consistently less infected than their more susceptible counterparts. Nevertheless, intensive cultural practices should be used with caution in areas where rust is a problem. SO (1131).

556. Cottonwood leaf beetle larvae defoliate willows as well as poplars. However, there is the possibility of developing a degree of protection to this insect by growing more resistant trees. A test in Mississippi showed that defoliation among 37 clones of black willow ranged from a low of 21 and a high of 95 percent, while two clones of the cross, Salix babylonica x S. alba and three clones of the sandbar willow had less than 10 percent defoliation. These tests clearly indicate that a degree of resistance does exist and it will be possible for the tree improver to select for it. SO (1132).

557. Loblolly pine, the most important commercial pine species in the southeastern United States, is susceptible to damage by southern fusiform rust. A number of trees with a high degree of resistance to this disease have now been located in Florida, Louisiana, and southwestern Mississippi. Stands nearest the Gulf Coast in Alabama and Mississippi were least resistant and resistance increased gradually to the north and west. These results provide a workable guide for the efficient selection for rust-resistant loblolly pine for future plantings within the study area and probably outside it as well, since the area covered is representative of most of the loblolly range. SO (1133).

4. TREE BREEDING METHODOLOGY

558. Efficient techniques for controlled pollination in white oak are essential for its genetic improvement. In tests conducted in both Mississippi and Connecticut, successful hybrids have now been produced with both

fresh pollen and pollen stored for 1 year. The use of stored pollen will enable white oak breeders to accelerate their genetics programs since they can make rangewide crosses. SO (1134).

559. An understanding of the mechanism of the chemical stimulation of rooting would be useful in the vegetative production of genetically superior trees. Studies in India with Salix, Populus, and Hibiscus have clearly demonstrated that the effectiveness of common rooting hormones is influenced by the nutritional status of the cutting. For successful rooting there is a need for a balance between the applied hormone and the carbohydrate content of the cutting, and this balance varies between trees of the same species as well as between species. WO (1135, 1136, 1137).

560. Methods are needed to determine if variation in competitive ability exists in slash pine and how to test for it. A genotype x environment stability procedure which subjected related families to severe nursery conditions of limited space and moisture proved useful for isolating differences between families in growth. Some families grow better under stress than other families. Volume production of plantations could be improved by planting only trees first selected for their better competitive ability at close spacing in the nursery. SO (1138).

C. Improving Use of Wood

1. WOOD AND TIMBER QUALITY

561. The anticipated shortage of timber has stimulated interest in accelerating wood production through rise of intensive cultural practices. The effect of prescribed levels of irrigation and fertilization on the wood quality of 6-year-old slash pine has been investigated and is now reported. Primary quality characteristic investigated was specific gravity, which was reduced by fertilization. Effect on secondary qualities such as grain orientation, clear length between whorls, number and diameter of branches, and percentage of latewood was also observed. FPL (812).

562. Hardwood lumber suffers loss in both volume and degrade during the air-drying process, but sawmills and wood-using plants have never known the magnitude. Detailed tabulated information is now available for 10 of the more important hardwood species showing how green lumber changes in volume and grade when seasoned to the rough air-dry condition. Average volume losses vary from 2 to 7 percent depending on species and grades. Availability of such data will enable estimates of losses to be made without regrading and remeasuring following air drying. NE (788).

563. Estimates of tree quality through use of tree grades have become of increasing interest to owners, buyers, and sellers of timber. An interim hardwood tree grade covering factory lumber, recently developed and approved by the Forest Service, provides grade volumes for yellow birch, red maple, and black oak trees. Tree grade specifications as well as associated lumber grade volumes are presented so that by applying current lumber prices the tree's value for lumber can be estimated. NE (794).

564. Question invariably arises as to what percent of the total cubic-foot content of a tree is used following harvest, and how much is left in the woods, the processing mill, or elsewhere. Averages developed from summaries of information gathered from various sources are now presented and provide some of the answers for western softwoods. Results show that about 75-85 percent of the total cubic-foot content of the tree is used, indicating that efficiency in the western softwood industry is perhaps greater than normally realized. PNW (789).

565. Recent limitations placed on burning have fostered an increased interest in the possibilities of developing economic procedures for manufacturing bark products. Research aimed at utilization of bark needs to consider the effect of variation and modification of bark structure on product properties and the possibility of developing a classification system based on external appearance. Research findings did not result in a system that could correlate anatomical characteristics of bark with external appearance, but several sources of bark variation that could be used to separate bark into quality classes, as they might affect bark product quality, were isolated. PNW (806).

566. Due to the increasing demand for lumber and impending possible timber shortages, white fir, once considered an "inferior" species is now in a position of being an important source of lumber. This has resulted in an increasing need for up-to-date information on grade recovery and other related aspects for this species. Details regarding grade and volume changes in surfacing and drying of over 43,000 board feet of white fir timber and analysis of results obtained are now available. Information of the type included is important to public and private agencies for timber appraisal and quality evaluation as well as to the lumber industry for updating processing procedures. PNW (803).

567. Detailed information on suitability of local timber resources for veneer production is needed to make sound decisions on location of new plywood facilities. Extensive information on veneer recovery by grades and sizes and yield by log grade and size has now been developed for Black Hills ponderosa pine, a species not previously utilized for commercial plywood production. Valuable resource and utilization guidelines are presented for considering the feasibility of establishing plywood plants in the Black Hills area. RM (816).

568. A variety of cultural treatments have been investigated for the purpose of enhancing timber growth and increasing yield per acre. A study on 7-year-old plantation-grown sycamore involving techniques of fertilization, thinning, and a combination of both, indicated greater species response to thinning than to fertilization in both radial growth and wood properties. Growing space becomes the limiting growth factor in sycamore after 4 years (planted 8 x 8), and forest managers should recognize the importance of growing space in attempting to maximize fiber production based on short rotations. SE (808).

569. The practice of purchasing southern pine timber on a weight basis has raised serious question as to possible seasonal variation in weight per unit volume due to variation in moisture content. Results of a recent study indicate a single weight factor can be applied to loblolly and slash pine trees found growing in the same location. Since there are no seasonal changes in weight, seasonal adjustments in the weight scaling factor are not necessary. SE (811).

570. Log and tree grade systems for eastern white pine have been developed and approved as standard for all Forest Service operations where grading of eastern white pine is necessary. Because of extreme variability in eastern white pine quality, these grading systems are necessary for accurate and consistent stratification of sawlogs and trees into distinct value classes for appraisal for sale or inventory purposes. Use of these grades provides buyer and seller with a better tool for estimating values and affords sawmill operators a device for better control of raw material entering the mill. NE (812).

571. Systems for determining yields of dimensions from top grades of walnut and alder lumber have been developed. Basic information for each grade for random-width material is presented with adjustments for determining yields in given widths. This allows yield and cost comparisons to be made using various grades and grade mixes to provide information on the most economical choice for specific cutting orders. Savings of several hundred dollars are obtainable in typical cutting orders through correct grade selection. FPL (809, 810).

572. The high-pitched scream or sirenlike sound of a saw in a sawmill or secondary manufacturing plant hurts the ears and may be detrimental to the workers' health. A solution to the screaming saw problems is now available. It involves a simple method of cutting symmetrically placed expansion slots in the rim of the sawblade. High, natural-frequency vibrations are thus suppressed to reduce sound within tolerable limits. FPL (798).

573. Production of lumber from logs involves, essentially, fitting rectangles into a circle, with the key to maximum lumber yield from any given size log being width of opening face or position of the first cut. A computer program has been developed which determines, for each log diameter, the width and position of the first saw cut made on the log which will maximize the yield of lumber products. Results indicate use of the best opening face (B.O.F.) system can enable sawmillers to recover at least 10 percent more than they are currently obtaining from small logs. FPL (792, 957).

574. Guidelines and preliminary rules for estimating volume of unsound wood associated with defects have now been developed for koa and ohia logs on the island of Hawaii. Frequent inconsistencies previously occurred between cruisers and graders since there was no good basis for decision. Evaluation of volume loss associated with defect indicators such as butt scar, conks, branch stubs, fork, and the like now provides for accurate reduction. PSW (786).

2. WOOD PRODUCTS AND WOOD PROCESSING

575. Stake tests on pressure and nonpressure treated southern pine have been under way in decay and termite exposure sites in Mississippi, Wisconsin, Louisiana, Florida, and the Canal Zone since 1938. Most recent observations indicate superficial treatment (3-minute dipping and brushing with preservatives such as creosote, copper napthenate, penta, and the like) adds from a few months to 4 years to untreated stake life. Some waterborne preservatives have provided less protection than preservative oils and others show results that compare favorably. FPL (834).

576. Accurate prediction of equilibrium moisture content (EMC) of wood is important in controlling wood product quality. A formula for predicting masses of data has been developed based on sorption theory and data. Results agree well with tabulated readings. Average deviation of calculated from tabulated values is less than 0.13 percent moisture content and deviation is never more than 0.9 percent. FPL (862).

577. Esthetically desirable and durable wood shingles and shakes have been restricted, in some applications, because of performance under fire conditions. Suitable fire retardancy would improve shingle and shake utility and insure consumer confidence and, to this end, numerous fire retardant treating systems have been evaluated. Four systems have shown excellent promise in providing fire retardant effectiveness following lengthy exposures to leaching and weathering: three chemical impregnation treatments and one impregnation followed by a coating. Economy and treatment levels--to establish optimum effectiveness--are yet to be determined, but basic screening of numerous possible systems has been accomplished. FPL (838).

578. Excessive water in paint film or in the wood under the film can cause blistering, peeling, or other unsightly failures of the wood finish. The types of damage caused by unwanted water or water vapor, the source, the manner in which it gains ingress to the film or wood, and possible remedies are discussed in a report written by the Forest Products Laboratory. Information is particularly helpful to homeowners in identifying failures, understanding the causes, diagnosing the problem, and taking corrective measures. FPL (871).

579. Dry lumber has many advantages in the manufacture of most wood products, but drying processes, regardless of system used, are costly and time consuming. A comprehensive manual on air drying practices and procedures, incorporating information resulting from recent research, is now available to assist mill and plant managers, yard foremen, lumber handlers, and others in analyzing their air drying practices and achieving maximum efficiency. Resulting faster drying and improved quality benefits both producer and consumer through lowered cost and reduction of loss or degrade. FPL (859).

580. Drying costs for oak, probably the most important United States hardwood, are high since it is very difficult to dry rapidly without considerable loss due to degrade. A preliminary Forest Service study investigating several possible methods of reducing degrade and drying costs of oak has been completed and suggests possible drying economies that may be attainable. Further study and analysis of commercial feasibility and applicability of suggested methods is necessary, but procedures that could prove beneficial to oak processors, either singly or in combination, are outlined. FPL (875).

581. Black walnut lumber continues to be highly prized for furniture, paneling, gunstocks, and the like, but the supply of high-quality black walnut trees is critically scarce. Much valuable black walnut dimension can be economically produced from short tree sections, tops, large branches, and other logging residues customarily left behind during logging operations. A procedure using bolter saws to produce short fitches which are then processed into dimension parts shows much promise in augmenting diminishing walnut supplies through more efficient utilization and improvement of forest environment through reduction of unsightly slash. NC (829, 872).

582. Aspen lumber machines easily, but fuzzy or chipped grain often results when conventional (parallel-to-the-grain) knife planers are used. Cross-grain planing produces superior surfaces, since defects are shallower than those produced by conventional planing, and subsequent processing and waste can be reduced.

Flakes suitable for panel products (particleboard, etc.) can also be manufactured simultaneously by cross-grain planing of aspen at 6 percent moisture content, thus requiring less conditioning prior to processing into particleboard. NC (868).

583. Frequency of chipped grain has previously been used as a basis for determining suitable rake angle in the planing of hard maple. Recent studies indicate that perhaps depth of machining defects rather than frequency may be a better guide to determining proper rake angle for surfacing many hardwoods. Proper rake angle, producing shallow defects, provides for reduced loss of material in further processing to achieve surface smoothness. NC (870).

584. Literature on southern pine bark structure is limited with only surface characteristics descriptions of some species being available. A comprehensive detailed study of the bark of the ten southern pines has been conducted, reporting anatomical and physical characteristics of the various bark layers and cells, as well as comparative properties of bark of the involved species. With bark utilization of timely importance, an analysis of bark structure could provide a basis for developing possible future uses. SO (839).

585. A recent process for rapid drying of southern pine studs from small logs or veneer cores has seen only limited application because of cutting size restrictions.

A more broadly applicable system of drying under restraint in a high-temperature kiln produces substantially straighter, higher grade studs with strength essentially equal to conventionally dried studs. The high-temperature schedule takes less than one-fourth the time and one-half the total energy required by the low-temperature schedule, and provides better resistance to subsequent warp under adverse conditions than conventionally dried studs. SO (842, 843).

586. The potential for cutting wood with a laser beam offers a number of advantages over conventional machining processes, including narrow kerf, no sawdust, minimal noise, and the like. In cutting southern pine wood with an air-jet assisted, carbon dioxide laser, maximum feed speed differs with material thickness, specific gravity, and moisture content. However, feed speed along the grain does not differ from feed speed across the grain. Laser cutting efficiency is low compared to conventional circular saw cutting, but other considerations offset this. SO (852).

587. The technology for formulating phenol formaldehyde resin adhesives for plywood has been well established, for the most part, by empirical means. Though the chemistry of the resins has been widely studied, little published data relating resin properties to wood adhesion is available. Information and data are now available relating bond quality and some of the physical and chemical properties of adhesives. Adequate definition of such relationships could lead to the eventual development of criteria for controlling both formulation and performance of glues. SO (840).

588. Southern pine bark is utilized in a number of industrial products and such uses will increase, but probably not fast enough to prevent disposal problems if incineration of waste is outlawed. The most promising process for large-volume disposal appears to be in use as a fuel. Technology and economics indicate it may be feasible to burn southern pine bark efficiently to generate steam in electric plants with little emission of pollutants. (846).

589. Southern pine wood can be successfully steam bent if the bending jig incorporates a flexible metal strap with a mechanism to apply uniform end compression load during bending. Steaming periods of 10 to 20 minutes per inch of thickness appear adequate. Edge-grained, fast-grown, low-specific gravity wood without cross grain provides the best stock for successful bends. SO (848).

590. The southern pines are an important national resource, and it is estimated they will provide the major source of softwood timber in years to come. Significant opportunities exist for increased utilization in both harvesting and manufacturing. The next decade will likely see rapid maturation of recent developments such as tree shears, chipping headrigs, whole tree utilization, new lumber and plywood manufacturing technology, and the like. SO (845).

591. A computer program has been developed that accepts basic field inventory from sample trees and determines stand potential for a number of individual primary products and combinations of products. The program can be used to grade or classify trees or sections of trees for all possible products or for individual products of greatest value in a specified order of preference. This provides the manager of a diversified timber operation with a tool to evaluate timber inventory data for the entire array of potential lumber products with possible conversion alternatives. RM (836).

592. Specific gravity is the simplest and most useful single index to suitability of wood for many uses. The presence of extractives in resinous species, however, may increase both magnitude and variability of this index beyond that warranted by the cell wall substance alone. This provides a chance of error in estimates of strength characteristics or pulp yields. Mean specific gravity of southwestern ponderosa pine is reduced approximately 12 percent by extractive removal, and an equation has been developed by which extracted specific gravity may be estimated based on measured unextracted specific gravity. RM (818).

593. To avoid possible surface checking, the moisture content of large laminated members at the time of fabrication should approximately equal that of the equilibrium moisture content (EMC) of the area where the timber is to be used. Equilibrium moisture contents measured seasonally for 3 years in laminated timbers exposed under a variety of exterior and interior conditions from South Dakota to Arizona (Rocky Mountain area) remained in a narrow range of 6.6 to 10.5 percent. Laminated timber producers should therefore fabricate at a moisture content of about 8 percent for laminated timbers to be used in that area. RM (854).

594. Oak has an advantage over other wood and nonwood materials for three industrial products: railroad crossties, returnable pallets, and laminated truck flooring. These products are the largest and fastest growing markets for oak. Producers of oak lumber should keep these products in mind in production planning, since the sizes used in their manufacture range from large to small and narrow, providing opportunity for improved utilization of logs. NE (857).

595. Machine-driving of wooden and steel guardrail posts is an accepted procedure, and wood has now been shown to be superior to steel in resisting damage when driven under adverse conditions such as rock-filled roadbeds. Blunt-bottomed wood posts produce cores of compressed earthen material at the base, which reduces required driving energy and protects the post from damage. Information should be of special importance to developers of State highway specifications. NE (831).

3. WOOD CHEMISTRY AND FIBER PRODUCTS

596. The quantity and composition of waste paper in combined or mixed refuse collected by the City of Madison, Wis., over a period of a year have been determined. Paper made up nearly 47 percent of the total

over the period. The waste paper contained 41 percent groundwood and 59 percent chemical pulp. Physical properties of papers made from reclaimed fiber were similar to those made from groundwood. FPL (894).

597. Research on the potential of waste wood and bark manufacturing residues as animal feeds continues. Alkali treatment of aspen sawdust renders it as digestible as hay, according to assay tests. The digestibility of aspen sawdust, aspen bark, and alkali-treated aspen sawdust by goats was determined. Results yielded apparent digestibilities of 41 percent for aspen sawdust, 52 percent for alkali-treated aspen sawdust, and 50 percent for young aspen bark. Use of these wood wastes as ruminant roughage and energy source provides a high-value outlet and diminishes disposal problems. FPL (890).

598. The chemical structures and quantitative distribution of new resin acids in the needles and young bark of slash pine have been determined. One of these resin acids, imbricataloic acid, comprises 24 to 64 percent of the needle resin acids. This information on needle extractives will be useful for evaluating logging wastes as a potential source for naval stores. FPL (902).

599. The oxidative decomposition of wood fiber polysaccharides such as cellulose is one of the major obstacles to the adoption of oxygen as a universal pulping agent in place of sulfur and chlorine, which are major causes of pollution in conventional pulping and bleaching operations. These oxygen-wood pulping reactions continue to be studied. Degradation products have been identified and quantified. Another new concept to suppress cellulose oxidation with potassium iodide was examined. Degradation was prevented, but the system appears impractical. FPL (891, 898, 899).

600. The annual production of bark residues from wood products manufacturing has been estimated at 400 million cubic feet. Bark could become an important source of useful chemicals. New terpenoid compounds have been identified in lodgepole pine bark. Six new derivatives of nordehydroabietane have been isolated from jack pine and western white pine barks. Anticopalic acid has been found to be a major constituent of the bark of western white pine and eastern white pine. These chemicals from bark are not yet of economic significance in themselves but may become significant in combination with naval stores or other bark or wood utilization operations. FPL (896, 897, 911, 913).

601. Pulpwood chips undergo significant deterioration in outdoor storage piles (approximately 1 percent per month) due to cell respiration, heat, micro-organisms, chemical action, and in some cases spontaneous combustion. Initial heating is caused by living cell respiration. Chemical reactions have greater significance as chip pile temperatures rise. Further testing of green liquor regenerated from kraft pulping wastes has shown that it provides effective control of deterioration in aspen chips as well as pine. FPL (886, 887, 903, 904).

602. Hardboards differ considerably in properties depending upon manufacturing variables. Eight variables in the manufacture of high-density, wet-formed hardboards were analyzed. Wood species proved statistically the most important factor in affecting dimensional stability with pressing temperature and method of refining also having an influence on this property. Type of resin had the greatest effect on strength and stiffness. Effects of pulp freeness, type of refiner, forming-water temperature, resin amount, pressing temperature, and tempering were also examined. This quantified analysis will assist manufacturers in using new raw materials such as forestry and agricultural wastes more effectively in producing better quality boards. FPL (906).

603. Most properties of paper are strongly dependent on moisture conditions; therefore, the specific relationships between paper properties and moisture content are of primary importance. A basic relationship exists between specimen equilibrium moisture content and the tensile strength properties of linerboards. Cyclic changes in relative humidity produce greater deformation and reduced serviceability of paper than does a constant, relative humidity environment. Stacked fiberboard containers are more likely to fail in an uncontrolled relative humidity environment than in a controlled, constant relative humidity environment, even though the average moisture content may be higher in the latter environment. FPL (877, 878).

604. The properties of paper and other woodpulp products are influenced by the properties of fiber and subfiber structures. Increased knowledge of cellulose and fiber structures will provide better understanding of the deformation behavior of paper. It has been proposed that wood fibers are formed with built-in tension and that fibrils are transformed during pulping. Pulping releases restraint of fibrils, permitting them to contract longitudinally and undergo perimeter reduction and S-helical twisting. This implies molecular rearrangements within the fibril which would contribute to changes in paper properties. FPL (907, 908, 909).

4. WOOD ENGINEERING

605. Compressive strength, vitally important in corrugated shipping containers, is closely related to edgewise compressive strength and bending stiffness of the combined board. Methods of determining the former were developed, but ways of accurately determining the latter were not known. Two methods of determining the bending or flexural stiffness of the combined board through determinations of component part properties have now been developed; both provide accurate, satisfactory results. These methods provide a quality control tool and means of predicting fiberboard properties that could otherwise be determined only through extensive and expensive empirical testing. FPL (932).

606. Control of finger joint location in tension laminates of commercially produced laminated timbers is not readily feasible, and the effect of such joints on strength of timbers must, therefore, be known. Tests on

large glued timbers indicate beams with finger joints at the midlength of the tension laminations (the most critical area) are as strong and stiff as those without finger joints in the same region. Results provide more accurate definition of factors affecting large glued beam strength and are essential in developing effective specifications. (938).

607. Producers and users alike need up-to-date information on efficient manufacturing practices to achieve maximum utilization of the wood used in the manufacture of over 125 million pallets per year. Pallet manufacture consumes almost 10 percent of our annual lumber production.

Results of recent research have been incorporated in a report which covers basic and fundamental wood concepts, characteristics, methods of fastening, pallet fabrication, construction, and design. The report provides a reference for the manufacturer promoting efficient raw material use as well as the purchaser interested in quality goods and satisfactory performance. FPL (922).

608. Evaluation of all possible combinations of nails of a variety of metals, shapes, and sizes used with numerous species of wood to establish design loads is an almost endless task. A FS study has derived a simple theoretical expression involving shear load and joint slip of laterally loaded smooth round nails which accounts for various properties of nail and wood. Results of the study can be used to establish design loads for nails to permit use at maximum efficiency without evaluating all combinations of nails and species. FPL (945).

609. Southern pine plywood used as exterior siding provides maximum racking strength, but affords a relatively poor base for paint or other surface coatings. A study has shown that southern pine plywood and paintable southern hardwood face veneers can be combined to produce a strong panel with superior finishing properties. This new panel shows excellent promise as an efficient and economical plywood siding or sheathing-siding material for houses or other structures. SE (924).

610. Open wood decks provide desirable outdoor living area and spaciousness in home design, but special precautions are necessary to avoid deterioration under adverse exposure conditions. The Forest Service has prepared a comprehensive guide describing proper materials, design, construction details, treatments, and finishes that insure years of satisfactory deck performance. Illustrations of "good" as well as "poor" practices are included to assure proper wood use. PNW (915).

611. Average mechanical properties of the clear wood of the four major southern pine species have been reestimated using a double sampling technique. Revised estimates of bending strength of slash and shortleaf are slightly higher than previous estimates, while those for longleaf and loblolly are slightly lower. Most recent results also indicate values for modulus of elasticity in bending and maximum crushing strength are lower than previously estimated for loblolly, longleaf, and slash. Variability is also greater than previously expected. FPL (917).

612. Oak as a species grouping is plentiful, but much of the supply is low in grade and of the "scrub" species. Recent technological developments have done much to remove certain stigmas associated with use of oak as a raw material for reconstituted panel products for which "scrub" species are suited. Several current commercial fiber products are being made from reconstituted oak and present research under way will result in other efficient uses. FPL (937).

613. Timber bridges are not obsolete as often assumed, and are still economic structures for many secondary road systems. Properly designed and adequately pressure treated with preservatives, they will give many years of low-maintenance service. Advanced design concepts under investigation will provide further economics and greater efficiencies in timber utilization. FPL (941).

5. MISCELLANEOUS

614. Wood has served from the earliest days of history as an efficient and economical construction material. It has remained competitive even though research and the technological improvements have been at a relatively low level. Many technological advances and more efficient uses of wood are attainable through research and implementation of results. A renewable resource that can be produced into products with low energy consumption and little environmental degradation, wood is likely to assume a more prominent role in the future. FPL (953, 955, 956).

(For an additional item see paragraph 3.)

D. Marketing Under-Used Species and Residues

615. Wood residues produced by secondary manufacturing plants in 11 midwestern States totaled about 241 million cubic feet of fine and coarse materials in 1970. Of this total, 55 percent was sold or used for industrial fuel, 11 percent was given away (mostly for animal bedding or mulch), and 34 percent was burned or dumped as waste. The relatively small volumes generated by many individual firms and the lack of nearby markets are the main reasons why more of this material is not marketed for some economic use. NC (27).

616. As part of an analysis of opportunities for increasing wood manufacturing and employment opportunities in the Black Hills, veneer recovery from Black Hills ponderosa pine sawtimber trees was studied. Results from the 144 trees sampled show a veneer recovery in grades and proportions more than sufficient to manufacture at least 3/8-inch C-D plywood. It is believed that these sample results are fairly representative of recoveries probable from the Black Hills ponderosa pine log resource. RM (36).

617. Bark residues continue to be a serious disposal problem to the sawmill industry. One potential use is as a mulch when seeding disturbed soils on strip-mined areas, highway roadbanks and similar areas. Preliminary experiments in West Virginia using power mulchers (straw blowers) for large-scale application of either raw or processed bark showed satisfactory results. Since labor required to feed bark into the blower was found to be excessive, some sort of mechanized feed system must be developed to make use of bark power mulchers economically feasible. NE (28).

618. A prerequisite to developing economic uses for bark residues is a reasonably accurate estimate of material available and its location. A study in western Montana provides estimates of bark produced at plywood and sawmill operations in four areas as defined by the regional transportation system. INT (31).

619. Prices paid for primary wood manufacturing residues (chips and sawdust) used for fiber products in Washington and Oregon show a pattern of gradually rising prices over the period 1956-1970. The trend pattern was not uniform, but consisted of sharp rise followed by periods of relatively little change. PNW (29).

620. Maryland, Pennsylvania, and West Virginia pallet manufacturers produced 6 million pallets (5 percent of national production) and used 150 million board feet of hardwood lumber in 1968. This study of the tristate pallet industry includes information on raw material purchases, sources of supply, and marketing patterns by size of establishment. NE (32).

621. Wood residues, particularly large chips, play an important role in the electric smelting of certain ferro-alloys. A survey of the electro-metallurgical industry in 1970 showed a total wood consumption of about 796,000 tons (green weight). Since much of the industry is concentrated in or adjacent to the Appalachian region, this industry provides a limited but worthwhile outlet for sawmill wood residues, low-grade roundwood, and logging residue. NE (35).

E. Supply, Demand, and Price Analysis

622. A pilot study of wood products used in the construction of apartment buildings in Pennsylvania for which construction contracts were awarded in 1965 showed the average use of lumber per unit to be 3,334 board feet. Plywood use averaged 1.16 square feet (3/8-inch basis) per square foot of floor area and 1,211 square feet per housing unit. Both hardboard and particleboard usage primarily was in millwork and averaged 156 and 97 square feet respectively per housing unit constructed. This pilot study has been expanded to provide similar information for total U.S. apartment construction in 1969. WO (59).

623. In 1970, the United States wood preserving industry treated over 260.3 million cubic feet of wood products. This was an increase of 2.7 percent over the volume treated in 1969. Poles, crossties, lumber, and timbers accounted for over 212 million cubic feet, or about four-fifths of the total. Of the remainder, fence posts and piling were most important. WO (50).

624. The rapid rise in log exports from the West Coast during the 1960's has created widespread divergency of opinion as to impacts and consequences. An examination of economic theory regarding exports reviews benefits and costs, and discusses guidelines for the formulation of log export policies. PNW (51).

625. While domestic consumption of hardwood plywood nearly tripled from 1960 through 1969, practically all of this market went to imported materials. A study of trends in hardwood plywood production and market outlook concludes that if domestic producers are to share in this growing market, they should consider including prefinishing of imported hardwood plywood in their production mix. NC (54).

626. Over one-fifth of all wood household furniture manufactured in the United States, is produced in North Carolina. In 1968 this segment of the furniture industry purchased approximately 300 million board feet of domestic lumber, 27 percent of which originated from within the State. Use of red oak, soft maple, and mixed pine species increased greatly over the volumes used in 1963, but the use of black walnut, sycamore, yellow-poplar, and the hickories declined significantly. SE (41).

627. Municipal fire laws and regulations frequently restrict the use of natural Christmas trees in public buildings. A sample of 80 major cities in the United States disclosed that three will not permit the use of natural trees in public places and 61 require that a tree must be fireproofed before use in schools, hospitals, or other places of public assembly. NE (49).

628. A quarterly analysis of production, prices, employment, and trade in Northwest forest industries provides current information on lumber and plywood production and prices; employment in the forest industries; international trade in logs, lumber, and plywood; volume and average prices of stumpage sold by public agencies; and other related items. PNW (44, 45, 46, 47).

629. Furniture "rounds" are a valuable market for better grade hardwood logs. Firms producing furniture rounds cannot afford inefficient material allocation or processing techniques. In a South Carolina study, operations research techniques were used to evaluate processing strategy under alternative choices of material inputs (log sizes), processing constraints, and product requirements. Operations research as demonstrated by this study can be a valuable aid in improving profitability of existing plants or evaluating investments in new plant facilities. SE (48).

PUBLICATION LIST AND INDEX

The index and the following list of Forest Service research publications are also printed as a separate to the Research Accomplishments 1972 report.

The first number(s) following the index term refers to the narrative statement in the Research Accomplishments 1972 report. Numbers in parentheses refer to the publication list.

Each publication is followed by an abbreviation denoting the Forest Service research unit best able to supply additional, detailed information and copies of the 1,138 publications listed. Abbreviations and addresses of the research units are:

- PNW - Director,
Pacific Northwest Forest and Range Experiment Station
809 NE 6th Avenue, P.O. Box 3141
Portland, Oregon 97208
- PSW - Director,
Pacific Southwest Forest and Range Experiment Station
1960 Addison Street, P.O. Box 245
Berkeley, California 94701
- INT - Director,
Intermountain Forest and Range Experiment Station
507 25th Street
Ogden, Utah 84401
- RM - Director,
Rocky Mountain Forest and Range Experiment Station
240 West Prospect Street
Fort Collins, Colorado 80521
- NC - Director,
North Central Forest Experiment Station
Folwell Avenue
St. Paul, Minnesota 55101
- NE - Director
Northeastern Forest Experiment Station
6816 Market Street
Upper Darby, Pennsylvania 19082
- SE - Director
Southeastern Forest Experiment Station
Post Office Building, P.O. Box 2570
Asheville, North Carolina 28802

SO - Director,
Southern Forest Experiment Station
T-10210 Federal Building
701 Loyola Avenue
New Orleans, Louisiana 70113

FPL - Director,
Forest Products Laboratory
North Walnut Street
P.O. Box 5130
Madison, Wisconsin 53705

ITF - Director,
Institute of Tropical Forestry,
University of Puerto Rico
Agricultural Experiment Station Grounds
P.O. Box AQ
Rio Piedras, Puerto Rico 00928

WO - Deputy Chief for Research
Forest Service
U.S. Department of Agriculture
Washington, D.C. 20250

PUBLICATIONS

FOREST ECONOMICS AND MARKETING RESEARCH

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Timber growing economics	7-15
Multiple-use economics.	16-19
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Inherent variation	1116-1127
Insect-disease resistance	1128-1133
Tree breeding methodology	1134-1138

Forest Economics and Marketing Research

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12. Guttenberg, Sam. 1971. Setting rotation age. La. State Univ. 20th Annu. For. Symp. Proc., p. 5-9. (SO)
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Forest Insect and Disease Research

FOREST DISEASE RESEARCH

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